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THE DEVELOPMENT OF A SYSTEM FOR
ENHANCED RADIONUCLIDE DETECTION

ANNUAL REPORT

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The Johns Hopkins University School of Medicine
Baltimore, Maryland 21205
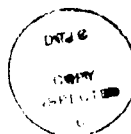
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Frequently, toxicologic processes involve concentrations of biologically active substances so low that to be detected, localized, and quantified they require attachment of appropriate radiolabels and subsequent autoradiography exposure periods that may extend for many months. The major objective of this research is to develop and deliver a system to reduce this long data collection period while maintaining the advantage of spatial resolution inherent in autoradiography.

After completing concept validation and after careful testing of three low-light-level camera system which were submitted by vendors for evaluation, a photon-limited camera and imaging system by Hamamatsu and a programmable image display unit by Gould were selected and ordered for purchase. Software programs to distinguish and analyze microstructures and their properties were generated.

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SUMMARY

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FOREWORD

Citations of commercial organizations and trade names in this
report do not constitute an official Department of the Army
endorsement or approval of the products or services of these
organizations.

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I. INTRODUCTION

The U.S. Army Medical Research and Development Command has a need to measure and accurately localize attogram concentrations of chemical compounds in animal and human tissues. Indirect enhancement of the specific energies of the molecules of these compounds is a fundamental approach to this problem.[59]

Enhancement involves the substitution of elements in the compound with their radioactive isotopes during synthesis. Less energetic radioactive isotopes, such as ^{14}C (0.156 MeV) and ^{3}H (0.01861 MeV), do not present difficult specimen handling problems and have half-lives of 5,570 and 12.3 years, respectively. They permit well-designed biological experiments to be conducted. The observed mode of decay for both ^{14}C and ^{3}H is β-emission. Depending upon the isotope being used, current methods require contact autoradiographic exposures of as much as 6 months to one year duration to record a usable image.[90]

Scintillation detection and counting by this method will be a more effective alternative, for detecting weak *β-emitting radionuclides*, than autoradiography. In this method, the energy of the β-particles excites a scintillator, which converts β-particle kinetic energy into potentially detectable photons. In this current effort, these photonic events are temporally and spatially accumulated as a function of position. The problem is being approached by demonstrating the feasibility of rapidly and microscopically imaging low-concentration radiolabeled tissues by developing: (1) methods for converting the energy of emitted β-particles to photons and (2) working instrumentation for recording the resulting scintillations with high spatial and temporal resolution.[12, 23, 31, 60, 91, 97]

II. MATERIALS AND METHODS

A.   Data Acquisition and Processing Systems

There are two major items of equipment whose purchases are essential for this contractual effort:

1) The Gould IP8400 Programmable Image Display Unit*, and

2) The Hamamatsu C1966-20 Video-Intensified Microscopy System (VIM)**.

While much of the thorough evaluation of each of these items was carried out during the previous year, it was completed in this year with decision to purchase. A request for approval was granted, and the order for this equipment was placed May 23, 1986.

B.   Development of Computer Software for Data Analysis

The program Particlet was obtained from our USAMRICD collaborator, R.K. Traub. The primary function of Particlet is to enumerate and to calculate the area of microstructures having intensity values above or below a user-supplied threshold. The results displayed to the user are:

1) threshold value,

2) particle count, and

3) total integrated area of counted particles.

In this context, a "particle" is defined as a contiguous set of pixels whose values all exceed or equal some threshold, and which are surrounded entirely by pixels whose values are all below that threshold.

Two modifications had to be made before Particlet could be incorporated onto our DEC VAX 11/780 system, worked upon to develop the data analysis program, and delivered to the Army in the format required on completion of the contract:

1) The first required the alteration of program code, so that image data were read in the form of byte-packed 8-bit data and then converted to the program format of 64-bit data.

2) The second was to increase the system working disk space to fifty thousand pages, because of the large virtual memory.

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* Gould, Inc., San Jose, CA

** Photonic Microscopy, Inc., Oakbrook, IL

A program called Microstructural Analysis Routine (MSAR) was then developed for this project by our computer scientist. This new program uses Particlet as a basic concept model and is written to analyze data for which Particlet had not been designed. MSAR thus offers a different data analysis and output of the extremely limited photon events (Section III. B.).

III. RESULTS

A. Data Acquisition and Processing Systems

1. Gould IP8400 Programmable Image Display Unit

The Gould IP8400 is a programmable digital image array processing and display unit. It contains look-up tables and special hardware processors to allow user manipulation of stored images and Random Access Memory (RAM) for image storage. In its present configuration it is attached to a VAX-11/780, as its host computer, as a peripheral device on the DEC Unibus.

Image data, acquired from the Hamamatsu C1966 VIM processor by the VAX-11/780, are transferred to the IP8400 RAM at a minimum rate of 1.5 Mbytes/sec. Currently the IP8400 has over 524 Kbytes of RAM in two 512 x 512 x 8-bit memory channels and in look-up tables and registers. Two users can access the IP8400 concurrently, but memory cannot be shared. Each display channel consists of one memory channel interfaced to a Video Output Controller (VOC) capable of driving a monochrome monitor or an RGB color monitor with composite video signals.

The master timing of the IP8400 is selectable and can be changed by software calls to internal registers. Each display channel can be manipulated by an associated joystick and has an alphanumeric overlay generator for producing annotation on the display monitor.

The IP8400 is also equipped with a high-speed pipeline processor, the Digital Video Processor (DVP), which will operate on a combination of 512 x 512 x 8-bit memories. It allows real-time operations such as multiply, add, subtract, compare, and reciprocal divide.

2. Hamamatsu C1966-20 Video-Intensified Microscopy System (VIM)

This is an extremely sensitive system developed for use in ultra low-light-level situations. Its characteristics include a wide dynamic range (to image over different intensity levels), high spatial resolution, a high signal-to-noise ratio, and real time data acquisition capabilities.

After evaluating three low-light-level cameras in the first year (Zeiss Venus, Dage-MTI, and the Hamamatsu C1966-20) and final system evaluations in this second year, the Hamamatsu C1966-20 VIM was chosen for purchase on the basis of its sensitivity and photon-limited characteristics.

The system converts emitted photons into a proportional number of electrons through the use of a two-dimensional photon counting tube that consists of three parts. On one face is a photocathode, where the initial optical image is focused. The photons are converted to electrons here and

subsequently accelerated to the second part of the counting tube, a two-stage microchannel plate (MCP), where they are amplified by electron avalanching. The MCP has two important qualities:

a) due to its design, the spatial integrity of the image is maintained and

b) because there is an adjustable gain setting, image intensifier gain (avalanching) can be controlled by the user.

The gain of the system can be operated in an analog mode, if sufficient light is present, or in digital mode for low-light-level imaging. Once the amplified electrons strike the phosphor screen that follows the MCP, a resultant image is presented to an optically coupled low lag vidicon. This produces signal pulses which may then be discriminated, with an acceptance threshold, to eliminate thermal noise that may occur.

The resolution approaches that of a Silicon Intensified Target (SIT) camera (300 to 350 TV lines as compared with 400 for the SIT). By selecting the type of intensifier and associated photocathode, a range of spectral sensitivity from 140 to 850 nm is possible.

The following is a list of the selected components:

a) Specially selected ultra-low noise/high resolution VIM photon counting camera head with optional Peltier cooling system. The Peltier cooling system was evaluated to determine its effectiveness in minimization of thermal noise. In addition, vendor specifications indicate that a dark count range of 5 to 10 cps can be achieved by carefully selecting the image intensifier tube.

b) VIM Controller and control keyboard. To reduce the number of incident light sources and thereby assure a light-tight laboratory environment, the keyboard has been adapted with a disable switch.

c) DEC DMA (direct memory access) interface and software. This feature directly couples the C1966-20 to the DEC VAX 11/780 computer memory, allowing digitized image data or control/command language to be transferred in either direction between the two devices. It offers the advantage of reducing the amount of user interaction necessary for operation of routine functions.

B. Development of Computer Software for Data Analysis

The Microstructrual Analysis Routine (MSAR) was developed to enhance the performance of the USAMRICD Program Particlet (Section II.B.), by providing additional functionality, in order to meet the need to quantitatively assess images derived from radionuclide-labeled sections obtained by the System under development. MSAR (Appendix A and Appendix B) has the ability to perform the following five functions:

1. Read Image Data into VAX 11/780 Memory

2. Define Region of Interest (ROI)

3. Select Threshold

4. Determine Adjacency Criteria

5. Calculate Microstructure Statistics

1. Read Image Data into VAX 11/780 Memory

The user may read a monochromatic, 512 x 512 pixel image from disk into VAX memory. The user is also requested to supply the physical dimension of the pixel in microns, if it is known. This factor is important in calculating the areas and perimeters of the microstructures.

2. Define Region of Interest (ROI)

A region of interest (ROI), which is defined by the user, is a subset of the full field image on which microstructure analysis is performed. If no region of interest is specified, the entire image field is used. The user selects an ROI by entering the X, Y coordinate values for the upper left and lower right corners of the region.

3. Select Threshold

Three types of thresholding specifications are available for user selection:

a) Minimum Threshold — all pixel values BELOW this value will be ignored during analysis,

b) Maximum Threshold — all pixel values ABOVE this value will be ignored during analysis,

c) Threshold Range — a combination of the above specifications such that only pixel values lying BETWEEN the minimum AND maximum, inclusively, will be used in analysis.

These selected thresholds must be values between 0 and 255 to be valid. In addition, the user is given the option of specifying a threshold increment for both the minimum and maximum threshold, either individually or together. This allows analysis to be performed in sequential steps automatically, thereby eliminating user interaction for repetitive operations.

4. Determine Adjacency Criteria

The user is given two choices in determining the criteria for contiguity of adjacent points: 1. Orthogonal; 2. Orthogonal and diagonal. If no adjacency mode is selected, the default is to number two.

5. Calculate Microstructure Statistics

MSAR performs a variety of microstructure calculations. For each specified threshold range of an image, the following are calculated:

a) Total area of all microstructures (in pixels)
b) Number of microstructures
c) Average object area
d) Average X,Y center of region of interest
e) Average X,Y weighted center of region of interest
f) Total number of perimeter points
g) Average number of perimeter points per object
h) Total perimeter length
i) Average perimeter length
j) Average horizontal and vertical feret diameters
k) Cumulative and average (per object) integrated optical densities
l) Average maximum optical density (per object)

The perimeter is calculated in two ways. The first, the total number of perimeter points, is the sum of all of the points on the boundary of the microstructure. The second, the total perimeter length, is the distance travelled, in pixels (or microns if the user supplied a pixel to micron conversion factor), of one complete trace of the perimeter. Once the microstructures have been uniquely labeled, the following statistical calculations are performed for each microstructure within a particular thresho'd range:

a) X,Y location of the geometric center
b) X,Y weighted center
c) Area
d) Total number of perimeter points and length
e) Maximum horizontal and vertical diameters
f) Integrated optical density (pixel values)
g) Average integrated optical density (pixel values)
h) Maximum optical density (pixel values)

Many of the calculation results from the preceding lists are given in units of length. For this reason, the pixel size is requested at the onset of the program. The results obtained will be more meaningful when MSAR is allowed to make calculations using actual dimensions.

The hardcopy results obtained upon the completion of Particlet and MSAR processing of the Experimental Image #ED0030 (Figure 1.) are given in Tables 1 and 2. While each routine offers the number of microstructures and the average area of these within a threshold range (or "slice level"), it is evident from this data that the results from MSAR are more extensive and useful. The information concerning averages is helpful in determining general data trends. For instance, the average weighted X and Y center can direct the user to the region of highest intensity, which corresponds to the region with the highest concentration of radiolabeled substance.

An additional level of detail in MSAR is illustrated in Table 3. Here information about specific microstructures is available for each unique microstructure in the image.

FIGURE 1. Concept Validation Image #ED0030 for Signal Dosimetry
Experiment with One-second Summation Time.
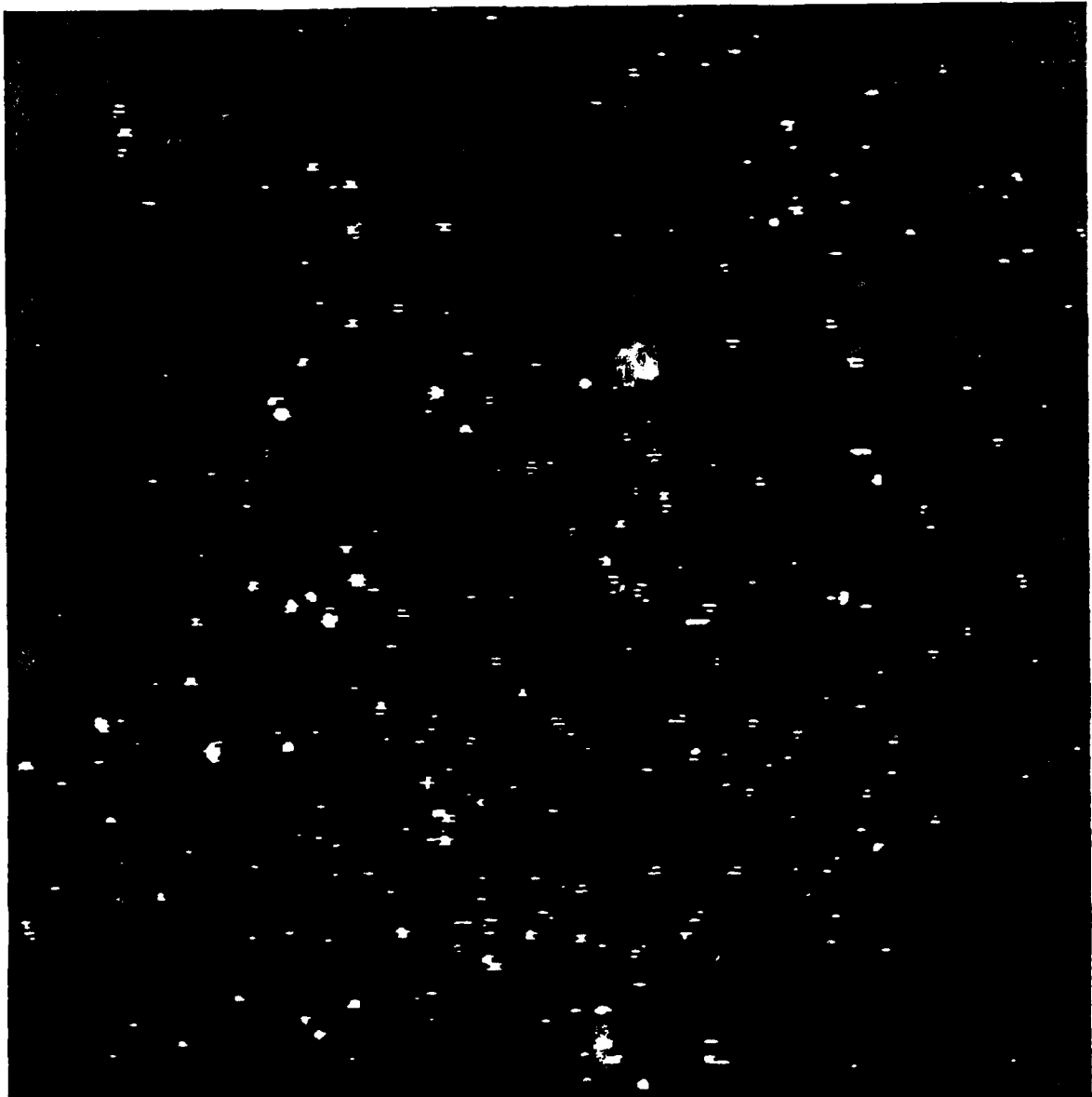
TABLE 1.   Tabulated Results from the Particlet Processing of
Experimental Image #ED0030

ED0030. DAT

slice level,	number,	area of particles
10. 00000	1	248303
20. 00000	345	1246
30. 00000	16	47
40. 00000	4	15
50. 00000	2	12
60. 00000	2	12
70. 00000	2	12
80. 00000	2	11
90. 00000	2	10
100. 0000	2	10
110. 0000	2	8
120. 0000	2	6
130. 0000	2	6
140. 0000	2	5
150. 0000	2	5
160. 0000	2	4
170. 0000	2	4
180. 0000	2	4
190. 0000	2	2
200. 0000	1	1
210. 0000	0	0
220. 0000	0	0
230. 0000	0	0
240. 0000	0	0
250. 0000	0	0

TABLE 2.   Tabulated Results from the MSAR Processing of
Experimental Image #ED0030

FILENAME = ED0030 DAT

REGION OF INTEREST   -   TOP LEFT (X= 1, Y= 1), BOTTOM RIGHT (X=512, Y=512)

THRESHOLD RANGE	TOTAL AREA	NUMBER OBJECTS (MICROSTRUCTURES)	AVERAGE OBJECT AREA	AVERAGE X- CENTER	AVERAGE Y- CENTER	AVERAGE WEIGHTED X- CENTER	AVERAGE WEIGHTED Y- CENTER
20-255	1246	345	3 61	255 19	303 44	234 48	309 66

THRESHOLD RANGE	TOTAL PERIMETER POINTS	AVERAGE PERIMETER POINTS PER OBJECT	TOTAL PERIMETER	AVERAGE PERIMETER PER OBJECT	AVERAGE HORIZ FERET DIAMETER	AVERAGE VERTICAL FERET DIAMETER	CUMULATIVE IOD	AVERAGE IOD PER OBJECT	AVERAGE ODmax PER OBJECT
20-255	287	0 83	346 00	1.00	2 44	1 45	31036	89 96	25 80

TABLE 3. Tabulated Results for a Particular Threshold Range from MSAR Processing of Experimental Image #ED0030 (Abridged)

FILENAME = EDOC30_C2C_255 MST   LOWER THRESHOLD = 20   UPPER THRESHOLD = 255
345 UNIQUE MICROSTRUCTURES FOUND
DEFAULT PIXEL SIZE =   1 000 MICRONS   FLAG = 1

UNIQUE MICROSTRUCTURE	X CENTER	Y CENTER	WEIGHTED X CENTER	WEIGHTED Y CENTER	AREA	PERIMETER COUNT	PERIMETER LENGTH	MAXIMUM HORIZONTAL RUN-LENGTH	MAXIMUM VERTICAL RUN-LENGTH	AVERAGE IOC	IOC	QDmax
1	223 00	27 63	222 96	27 63	6 00	-1	-1 00	3	2	2.12	26 50	30
2	223 00	30 00	222 96	30 00	3 00	-1	-1 00	3	1	75	23 00	28
3	54 50	37 00	54 49	37 00	2 00	-1	-1 00	2	1	31	22 50	26
4	54 00	39 00	53 99	39 00	3 00	-1	-1 00	3	1	77	22 67	26
5	108 00	39 00	108 00	39 00	1 00	-1	-1 00	1	1	23	23 00	23
6	220 30	39 00	220 47	39 00	2 00	-1	-1 00	2	1	43	21 50	23
7	322 50	42 00	322 36	42 00	2 00	-1	-1 00	2	1	46	24 00	27
8	108 00	43 00	107 90	43 00	3 00	-1	-1 00	3	1	67	29 00	33
9	243 00	43 00	242 95	43 00	2 00	-1	-1 00	3	1	77	23 67	27
10	176 50	44 00	176 56	44 00	2 00	-1	-1 00	2	1	48	24 00	27
11	106 00	45 00	105 99	45 00	3 00	-1	-1 00	3	1	76	21 33	27
12	258 50	62 00	258 50	62 00	2 00	-1	-1 00	2	1	46	23 00	23
13	138 50	66 00	138 44	66 00	2 00	-1	-1 00	2	1	43	22 50	25
14	206 50	69 00	206 49	69 00	4 00	-1	-1 00	4	1	97	24 25	26
15	248 50	72 00	248 49	72 00	2 00	-1	-1 00	2	1	46	23 00	24
16	249 00	74 00	248 97	74 00	3 00	-1	-1 00	3	1	72	24 00	26
17	434 50	74 00	434 43	74 00	2 00	-1	-1 00	2	1	46	23 00	26
18	169 50	79 00	169 33	79 00	2 00	-1	-1 00	2	1	45	22 50	24
19	290 00	79 00	289 94	79 00	3 00	-1	-1 00	3	1	70	23 33	25
20	237 50	80 00	237 44	80 00	2 00	-1	-1 00	2	1	45	22 50	25
21	290 00	81 00	289 94	81 00	3 00	-1	-1 00	3	1	70	23 33	25
22	348 50	82 00	348 47	82 00	10 00	-1	-1 00	4	3	240	24 00	26
23	215 50	89 00	215 53	89 00	2 00	-1	-1 00	2	1	45	22 50	24
24	239 00	92 00	238 93	92 00	3 00	-1	-1 00	3	1	70	23 33	25
25	162 00	97 00	162 00	97 00	1 00	-1	-1 00	1	1	20	20 00	20
26	344 00	99 00	344 00	99 00	1 00	-1	-1 00	1	1	21	21 00	21
27	336 00	103 00	335 93	103 00	3 00	-1	-1 00	3	1	70	23 33	25
28	306 50	106 00	306 49	106 00	2 00	-1	-1 00	2	1	47	23 50	24
29	323 50	110 00	322 56	110 00	2 00	-1	-1 00	2	1	45	22 50	25
30	417 00	111 00	417 00	111 00	1 00	-1	-1 00	1	1	20	20 00	20
31	243 50	112 00	243 46	112 00	2 00	-1	-1 00	2	1	46	23 00	23
32	417 50	113 00	417 54	113 00	2 00	-1	-1 00	2	1	46	23 00	25
33	246 00	114 00	245 94	114 00	3 00	-1	-1 00	3	1	45	23 00	24
34	390 00	121 00	389 94	121 00	3 00	-1	-1 00	3	1	69	23 00	25
35	280 50	123 00	280 50	123 00	2 00	-1	-1 00	2	1	50	22 00	25
36	29 50	126 00	29 49	126 00	2 00	-1	-1 00	2	1	49	24 50	25
37	89 00	127 00	89 02	127 00	3 00	-1	-1 00	3	1	81	27 00	31
38	28 50	128 00	28 56	128 00	2 00	-1	-1 00	2	1	45	22 50	25
39	88 50	129 00	88 44	129 00	4 00	-1	-1 00	4	1	135	33 75	38
40	334 40	133 10	334 38	133 06	10 00	-1	-1 00	4	4	23	23 40	26
41	91 17	137 08	91 10	137 17	12 00	11	14 00	5	3	313	26 00	27
42	358 50	142 00	358 51	142 00	2 00	-1	-1 00	2	1	47	23 50	24
43	387 00	142 00	387 00	142 00	1 00	-1	-1 00	1	1	26	26 00	26
44	90 50	144 00	90 45	144 00	2 00	-1	-1 00	2	1	44	22 00	24
45	89 00	146 00	89 00	146 00	1 00	-1	-1 00	1	1	25	25 00	25

To examine the integrity and accuracy of the Microstructural Analysis Routine, a test image was synthesized (Figure 2).

FIGURE 2. Microstructural Analysis Routine Test Image

Figure 2a. Digital Representation

10	10	20	20	0	30
0	20	50	40	10	0
10	20	10	30	10	20
0	10	10	0	40	0
0	30	30	40	50	30
30	20	20	0	40	40

FIGURE 2b. Analog Representation from Monitor
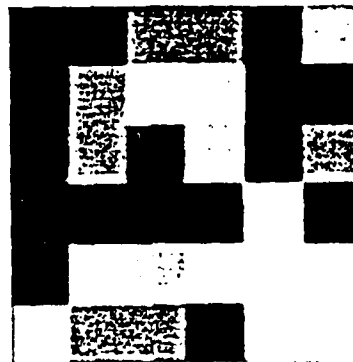
This test image consists of a six by six matrix containing multiples of six different numerical (pixel) values ranging from zero to fifty in increments of ten. These values were arranged so that, as MSAR processed the image (first by analyzing the 0 to 255 threshold range, then 10 to 255, and so on, until the lower threshold value was equal to fifty), the pixels that fell within the threshold range formed test patterns representing the various conditions of pixel contiguousness (Figure 3). Table 4 shows the results of MSAR execution on the test matrix image.

FIGURE 3.   Test Patterns of Pixel Contiguousness for Different Threshold Ranges of the Microstructure Detection Test Image
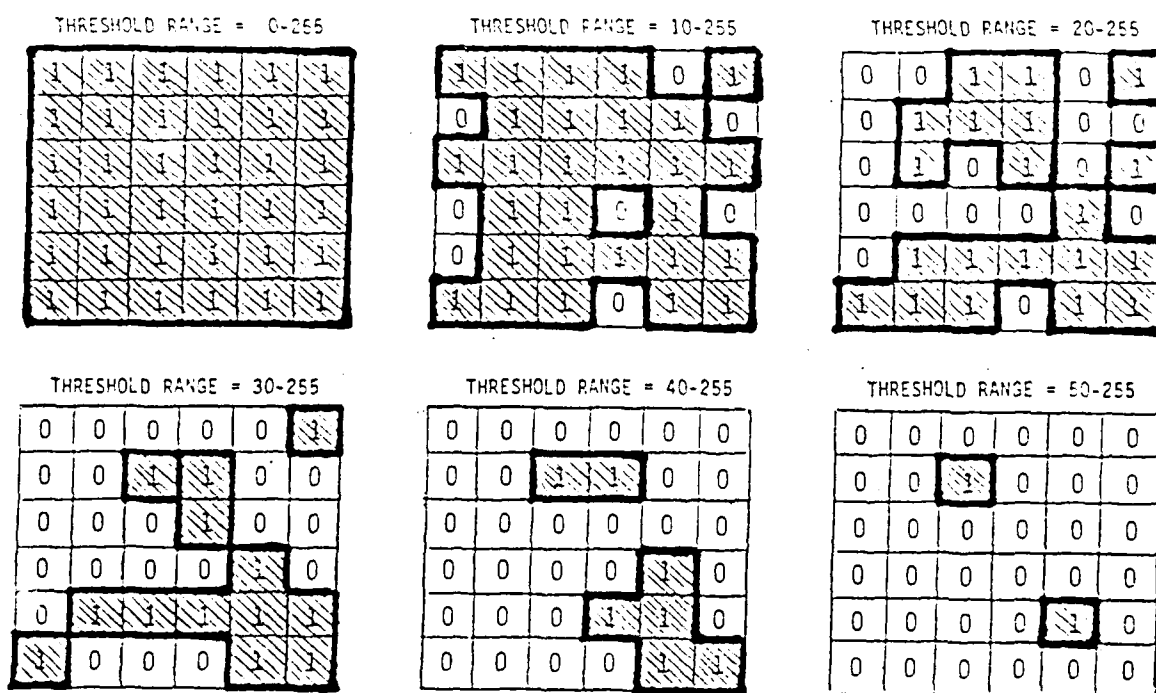
TABLE 4. Tabulated Results from MSAR Processing of
Microstructure Detection Test Image

Table 4a

FILENAME = TSTOBJ DAT

REGION OF INTEREST = TOP LEFT (X= 1,Y= 1), BOTTOM RIGHT (X= A,Y= A)

THRESHOLD RANGE	TOTAL AREA	NUMBER OBJECTS (MICROSTRUCTURES)	AVERAGE OBJECT AREA	AVERAGE X-CENTER	AVERAGE Y-CENTER	AVERAGE WEIGHTED X-CENTER	AVERAGE WEIGHTED Y-CENTER
0-255	36	1	36 00	3 50	3 50	3 50	3 50
10-255	28	2	14 00	4 70	2 30	5 52	3 45
20-255	20	4	5 00	4 74	5 84	3 78	3 99
30-255	12	4	3 25	3 79	5 61	4 17	4 22
40-255	7	2	3 50	4 25	3 40	4 55	4 24
50-255	2	2	1 00	4 00	3 50	4 00	3 35
60-255	0	0	0 00	0 00	0 00	0 00	2 20
70-255	0	0	0 00	0 00	0 00	0 00	0 00
80-255	0	0	0 00	0 00	0 00	0 00	0 00
90-255	0	0	0 00	0 00	0 00	0 00	0 00
100-255	0	0	0 00	0 00	0 00	0 00	0 00
110-255	0	0	0 00	0 00	0 00	0 00	0 00
120-255	0	0	0 00	0 00	0 00	0 00	0 00
130-255	0	0	0 00	0 00	0 00	0 00	0 00
140-255	0	0	0 00	0 00	0 00	0 00	0 00
150-255	0	0	0 00	0 00	0 00	0 00	0 00
160-255	0	0	0 00	0 00	0 00	0 00	0 00
170-255	0	0	0 00	0 00	0 00	0 00	0 00
180-255	0	0	0 00	0 00	0 00	0 00	0 00
190-255	0	0	0 00	0 00	0 00	0 00	0 00
200-255	0	0	0 00	0 00	0 00	0 00	0 00
210-255	0	0	0 00	0 00	0 00	0 00	0 00
220-255	0	0	0 00	0 00	0 00	0 00	0 00
230-255	0	0	0 00	0 00	0 00	0 00	0 00
240-255	0	0	0 00	0 00	0 00	0 00	0 00
250-255	0	0	0 00	0 00	0 00	0 00	0 00

Table 4b

(continuation, to the right, of Table 4a)

| THRESHOLD RANGE	TOTAL PERIMETER POINTS	AVERAGE PERIMETER POINTS PER OBJECT	TOTAL PERIMETER	AVERAGE PERIMETER PER OBJECT	AVERAGE HORIZ DIAMETER	AVERAGE VERTICAL FERET DIAMETER	CUMULATIVE IOD	AVERAGE IOD PER OBJECT	AVERAGE ODmax PER OBJECT
0-255	20	20 00	20 00	20 00	6 00	6 00	700	700 00	50 00
10-255	23	11 50	28 00	14 00	3 50	3 50	700	350 00	45 00
20-255	0	0 00	0 00	0 00	2 50	2 00	620	155 00	37 50
30-255	0	0 00	0 00	0 00	2 25	1 75	480	120 00	40 00
40-255	0	0 00	0 00	0 00	2 00	2 00	300	150 00	50 00
50-255	0	0 00	0 00	0 00	1 00	1 00	100	50 00	50 00
60-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
70-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
80-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
90-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
100-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
110-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
120-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
130-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
140-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
150-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
160-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
170-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
180-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
190-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
200-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
210-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
220-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
230-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
240-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00
250-255	0	0 00	0 00	0 00	0 00	0 00	0	0 00	0 00

C.   Literature Review

Emphasis has been placed on generating and updating a cumulative bibliography pertaining to this project (page 27). For literature to be included in the bibliography, it must first satisfy one or more of the following criteria:

1.   Alternative and comparable approaches to autoradiography, such as high-speed autoradiography and scintillation autoradiography.

2.   Physical modelling, such as the energy transfer between a radionuclide and scintillant, and single photon detection and capture.

3.   Specimen preparation techniques, such as animal tissue and glass-slide preparation, availability and assortment of radionuclides and scintillants, and techniques of scintillation counting.

4.   Video intensified microscopy, such as photodetectors and their available technology (photomultiplier tubes, charge-coupled devices, microchannel plates), signal processing (noise analysis and filtering), image processing and enhancement, and the analysis, display and communications of data.

IV. DISCUSSION

The Microstructural Analysis Routine (MSAR) was designed and implemented to address a set of experimental needs for this work. Specifications required that program execution time be minimized without additional computing hardware, and that two types of output files be created for each specified threshold range.

Upon program execution, one file contains an array of the uniquely labeled microstructures and, in addition, any information concerning the creation of the file or necessary for image display. Another file contains the calculated statistics for each unique microstructure. A third file is generated which gives the total and average microstructure statistics for the threshold ranges of a particular image. Additional specifications pertaining to the analyses performed by MSAR were also stipulated:

1. Read Image Data into VAX 11/780 Memory
2. Define Region of Interest (ROI)
3. Select Threshold
4. Determine Adjacency Criteria
5. Calculate Microstructure Statistics

These are described in detail in Section III. B.

A test image containing various patterns, created by varying pixel intensity levels within a matrix, was produced to examine the accuracy of the Microstructural Analysis Routine. These patterns simulated microstructures with edge points on the matrix boundary, with diagonal connections, and with holes. Results indicate that microstructures are being detected and analyzed as designed.

Using MSAR, the linearity of the system response as a function of integration time was assessed (Figure 4). In this plot the pixel count above threshold is shown as a function of the integration time. The ratio of photoevent area to full image field is given as a percentage and is printed adjacent to each data point. There is a linearity of the relationship for unsaturated images (i.e., when less than 44.5% of the image field is affected) indicating that, for a fixed source, the integration time is proportional to the cumulative area of the detected photoevents, until saturation effects alter this correlation due to overlapping events. Saturation begins to affect this linear relationship once the photoevent density reaches a concentration greater than 44.5% of the image field (Figure 4). At this value, continuing accumulation results in a progressively higher rate of overlapping points. All points are counted only once, hence leading to an underestimation of photoevents after the saturation point is reached.

FIGURE 4. Plot of Image Area above Threshold versus Signal Integration Time
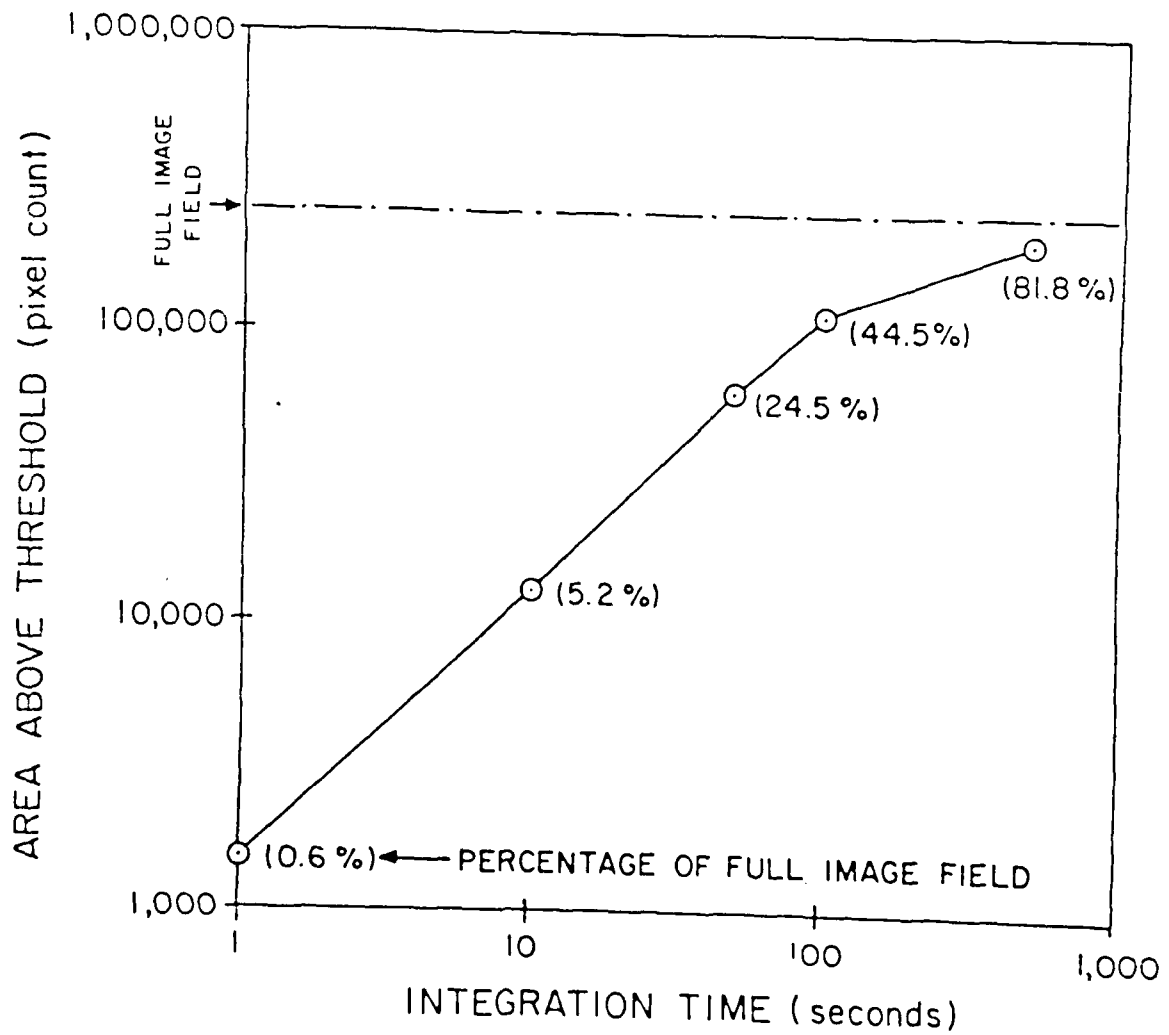
V. CONCLUSIONS

During this second year, final system evaluations of The Hamamatsu C1966-20 VIM Photonic Microscopy System and the Gould IP8400 Programmable Image Display Unit were carried out. Upon receiving official approval, purchase of the items was ordered.

A Microstructural Analysis Routine (MSAR) was developed to analyze the extremely photon-limited events recorded by the System under development. A program (Particlet) obtained from the United States Army Medical Research Institute of Chemical Defense (USAMRICD) was used as a fundamental concept in successfully accomplishing this task.

Two peer-reviewed scientific manuscripts reporting upon significant aspects of the work to date were prepared and presented, accepted for publication, or published during this reporting period:

"Detection and Localization of Quantum-Limited Events from Radionuclide Labeled Material by Computer Enhanced Video Microscopy." RK Traub, NJ Pressman, JK Frost, PK Gupta, RL Showers, GW Gill, DL Cook and JK Frost, Jr. In the Optical Society of America's Topical Meeting on Quantum Limited Imaging and Image Processing Technical Digest, 86(6):63-66, 1986.

"A Quantitative Method for the Detection and Localization of Quantum-Limited Events From Radionuclides in Cells and Tissue Sections by Computer Enhanced Video Microscopy." NJ Pressman, JK Frost, PK Gupta, RL Showers, GW Gill, DL Cook, JK Frost, Jr and RK Traub. Presented at the International Academy of Cytology's Fifth International Conference on Automation of Diagnostic Cytology and Histology, Brussels, Belgium, May 30-June 1, 1986. Analyt Quant Cytol Histol, (accepted for publication).

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GLOSSARY

OF SELECTED KEY TERMS, UNITS, AND ABBBREVIATIONS

AChE	-Acetylcholinesterase
attogram	- 10^{-18} gram
ASA	- American Standards Association, speed of photographic film
BIDAS	- The Johns Hopkins Biomedical Image Data Analysis System
Ci	- Curie = 3.7 x 10^{10} disintegrations per second
^{14}C	- Radioactive Carbon isotope with atomic mass of 14
C1966-20	- Hamamatsu VIM image processing system
CFIAC	- Cytotechnologist Fellow, International Academy of Cytology
cpm	- Counts per minute
cps	- Counts per second
DAGE-MTI	- Dage-MTI, Inc., Michigan City, IN 46360
DAMD17-84-C-4222	- USAMRICD Contract for "The Development of a System for Enhanced Radionuclide Detectors" with JHU
DEC	- Digital Equipment Corporation, Northboro, MA 01532
dps	- Disintegrations per second
EM	- Electron Microscopy
femtogram	- 10^{-15} gram
feret diameter	- The maximum diameter of a structure in a given direction
FIAC	- Fellow, International Academy of Cytology
FITC	- Fluorescein Isothiocyanate
flux	- Rate of transfer of particles or energy per unit area
GOULD	- Gould Inc., DeAnza Imaging & Graphics Division, San Jose, CA 95131
h	- Planck's constant = 6.62363 x 10^{-34} joule-second
^3H	- Isotope of Hydrogen with atomic mass of 3
IAC	- International Academy of Cytology
IOD	- Integrated Optical Density
JHMI	- The Johns Hopkins Medical Institutions
JHU	- The Johns Hopkins University
mCi	- Millicurie = 10^{-3} curie
MCP	- Microchannel Plate

MIAC	– Member, International Academy of Cytology
MSAR	– The Microstructural Analysis Routine
OD_{max}	– Maximum Optical Density
OSA	– Optical Society of America
Particlet	– Particle counting and sizing program developed by USAMRICD
P^2/A	– Perimeter squared divided by Area
PI	– Principal Investigator
pixel	– Picture element
PMI	– Photonic Microscopy, Inc., Oak Brook, IL 60521
PMIAC	– Professional Member, International Academy of Cytology
RFP	– Request for Proposals
RGB	– Red/Green/Blue
ROI	– Region of Interest
slice-value	– Boundary value for a threshold range
specific activity	– Activity (i.e., disintegrations per second) in (micro-, milli-) curies of radioactive species per unit mass or concentration of non-radioactive material (e.g., 56 mc C^{14}/mM experimental material)
S/N	– Signal to Noise ratio
^{35}S	– Isotope of Sulfur with atomic mass of 35
USAMRICD	– U. S. Army Medical Research Institute for Chemical Defense
USAMRDC	– U. S. Army Medical Research and Development Command
VAX-11/780	– DEC 32-bit computer
VENUS	– Zeiss low-light-level video camera
VIM	– Video Intensified Microscopy
ZEISS	– Carl Zeiss, Inc., Thornwood, New York 10594

APPENDICES

Appendix A.   MSAR Flowcharts

MAIN PROGRAM: EDC_MSAR

START

DISPLAY INFORMATION TEMPLATE TO USER.

ALLOW USER TO SELECT OPTION WITH CURSOR

NEW FILENAME? — YES → NFNAME

NEW REGION OF INTEREST? — YES → DEFROI

NEW THRESHOLD RANGES? — YES → SETTHR

NEW ADJACENCY CRITERIA? — YES → ADJCRI

EXECUTE? — YES → EXCUTE

ANALYZE STATISTICS? — YES → ANLZST

QUIT? — YES → CLEAR SCREEN → STOP
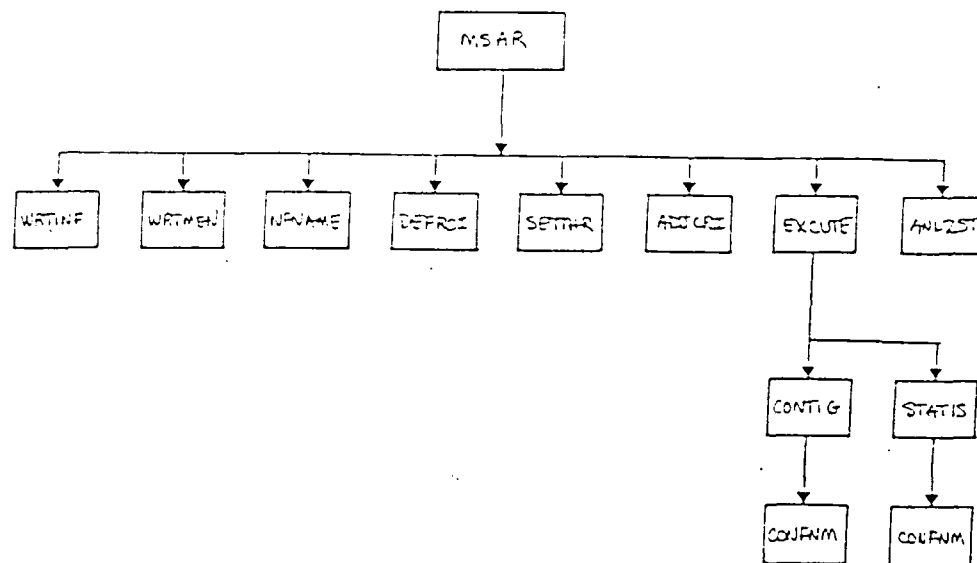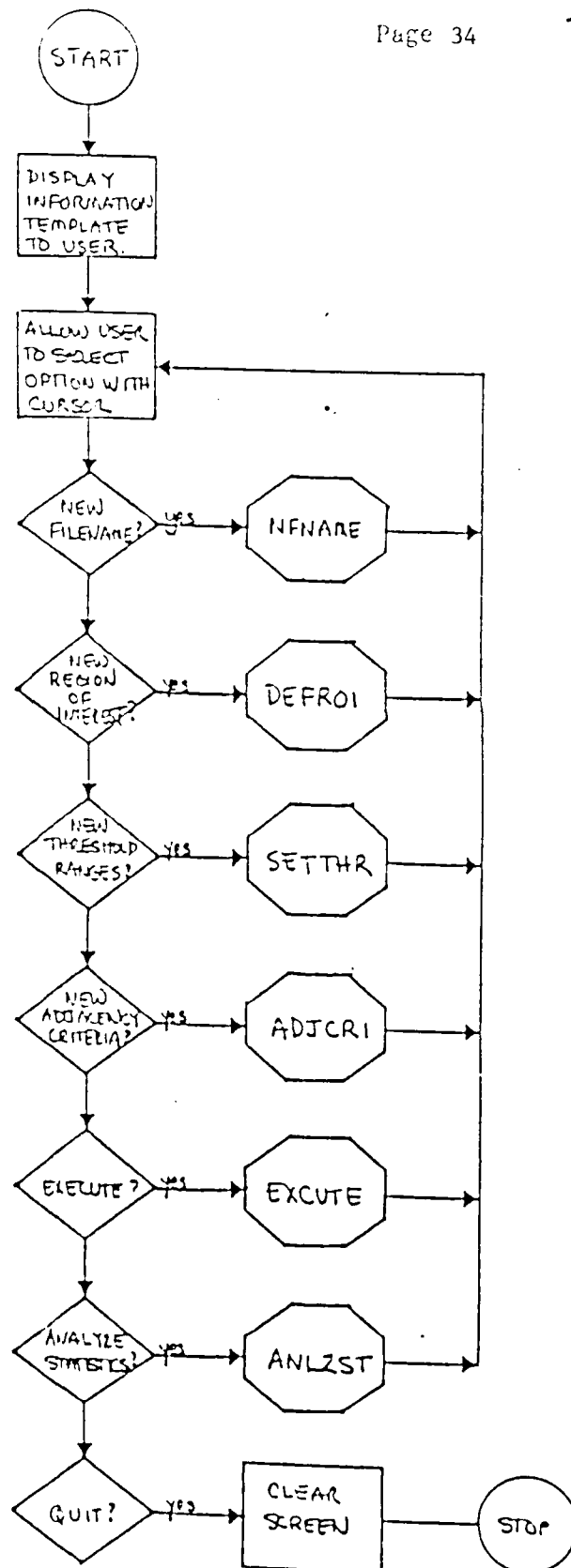
SUBROUTINE: NFNAME

-SUPPLY IMAGE FILENAME
AND READ IMAGE INTO
VAX MEMORY.

```
                    ( START )
                        |
                        v
              +------------------+
              |  PROMPT          |
              |  USER FOR        |
              |  INPUT           |
              |  FILENAME        |
              +------------------+
                        |
                        v
                 /  FILENAME  \        NO
                <   ENTERED?    >----------> ( RETURN )
                 \            /
                        | YES
                        v
              +------------------+
              |  READ            |
              |  INPUT           |
              |  FILE            |
              |  HEADER          |
              +------------------+
                        |
                        v
       NO        /  MORE       \
   +-----------<   THAN 1 CH    >
   |            \  HEADER?     /
   |                   | YES
   |                   v
   |          +------------------+
   |          |  PROMPT          |
   |          |  USER WHICH      |
   |          |  CHANNEL         |
   |          |  TO USE          |
   |          +------------------+
   |                   |
   |                   v
   |          +------------------+
   +--------->|  PROMPT USER     |
              |  FOR PHYSICAL    |
              |  DIMENSIONS      |
              |  OF PIXEL        |
              +------------------+
                        |
                        v
        YES      /            \
   +-----------<    ENTRY?      >
   |            \            /
   |                   | NO
   |                   v
   |          +------------------+
   |          |  SET SIZPIX=1    |
   |          |  AND SET         |
   |          |  FLAG=1          |
   |          +------------------+
   |                   |
   |                   v
   |          +------------------+        +------------------+
   +--------->|  READ            |        |  WRITE INFO      |
              |  IMAGE INTO      |------->|  TO              |------> ( RETURN )
              |  I*2 ARRAY       |        |  TERMINAL        |
              |  IMAGE(x,y)      |        +------------------+
              +------------------+
```
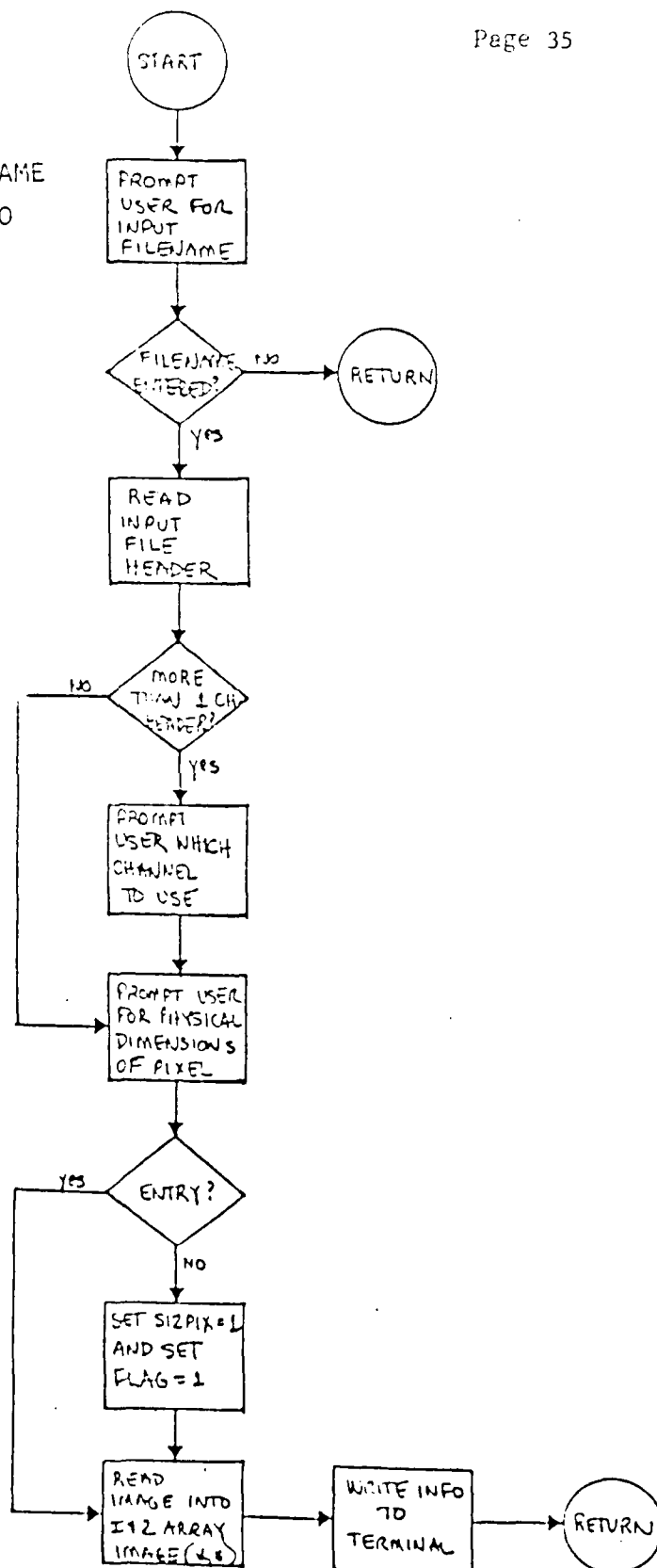
SUBROUTINE: DEFROI

-ALTER REGION OF INTEREST
(ROI) OF IMAGE THAT THE
CALCULATIONS ARE
PERFORMED WITHIN.

START

PROMPT USER
TO SELECT TO
PICK ROI BY
KEYPAD OR
BITPAD

KEYPAD? — YES

PROMPT AND
ACCEPT TOP
LEFT X,Y &
BOTTOM RIGHT
X Y

WRITE NEW
ROI
TO USER
TERMINAL

RETURN

NO

INIT. IPB500,
DISPLAY
IMAGE AND
ENABLE
CURSOR/BITPAD

USER SELECTS
TOP LEFT WITH
BITPAD, MOVE
CURSOR WITH
BITPAD

WHEN SELECTED,
RECORD
DISPLAYED X,Y
COORDINATES

USER SELECTS
BOTTOM RIGHT
WITH BITPAD MOVE
CURSOR WITH
BITPAD

WHEN SELECTED,
RECORD
DISPLAYED X,Y
COORDINATES

CLEAR/DETACH
IPB500. WRITE
NEW ROI TO
USER TERMINAL

RETURN

SUBROUTINE: SETTHR

-ALTER THRESHOLD VALUES.
THESE DETERMINE RANGE
OF PIXEL VALUES
CONSIDERED IN ANALYSIS.

START

PROMPT USER
TO ENTER
INITIAL LOWER,
UPPER THRESH

PROMPT USER
TO SELECT
INCREMENTATION
THRESHOLD

INCREMENT?

NO

SET INCREMENT
FLAG = Ø,
LOWER_INC = Ø
UPPER_INC = Ø

PROMPT USER
FOR
LOWER_INCR
&
UPPER_INCR

SET
INCREMENT
FLAG = 1

WRITE NEW
THRESHOLD
INFO TO
USER TERMINAL

RETURN
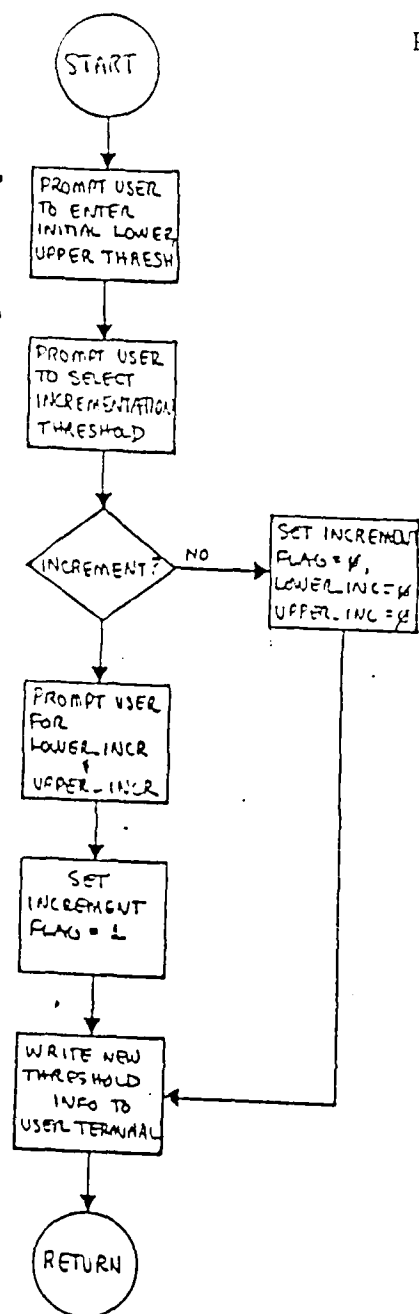
SUBROUTINE: ADJCRI

-ALTER RULE GOVERNING
CRITERIA FOR DETERMINING
ADJACENCY OF
NEIGHBORING PIXELS.

START

FROMPT USER
TO SELECT
'ORTHO' OR
'ORTHO/DIAG'

PRINT
NEW ADJAC.
CRITERIA
TO TERMINAL

RETURN
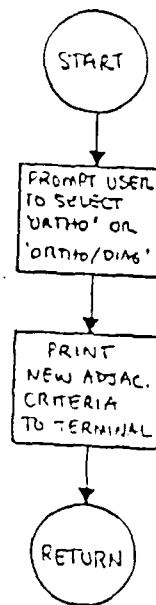
SUBROUTINE: EXCUTE

-PERFORM MICROSTRUCTURAL
 DETECTION AND ANALYSIS.

START

WRITE
'CALCULATING'
AND ESTIMATE
OF COMPLETION

WRITE
THRESHOLD
RANGE TO TERM.
THRESHOLD
IMAGE → THRESH

CONTIG

STATIS

INCREMENT
FLAG=1?   NO

YES

INCREMENT
BOTH LOW
UPPER
THRESHOLDS

OUTSIDE
VALID
RANGE?   YES

RESET
THRESHOLD
VALUES TO
INIT VALUES

WRITE INFO
TO
TERMINAL

RETURN
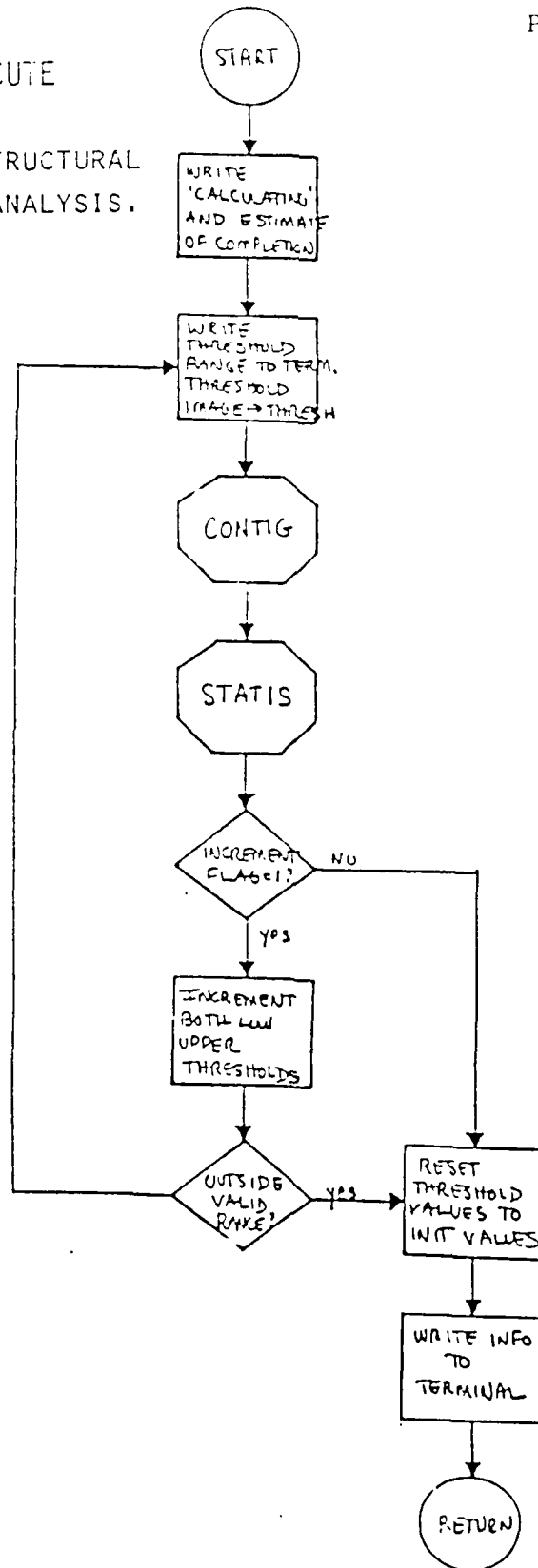
SUBROUTINE: CONTIG

-DETERMINE ADJACENCY
OF PIXELS AND
ASSIGN PIXELS TO
DISTINCT
MICROSTRUCTURES.

START

LOOP THROUGH
IMAGE USING
ADJCRI TO
CALCULATE
CONTIGUITY

IF N MVERGE
SELECTION,
MODIFY THRES
D UNIQUE #

COMPLETE?

NO

YES

WRITE ACL
FORMAT
HEADER, ALSO
ROI INFO TO FILE

WRITE THRESH
TO OUTPUT
FILE

RETURN
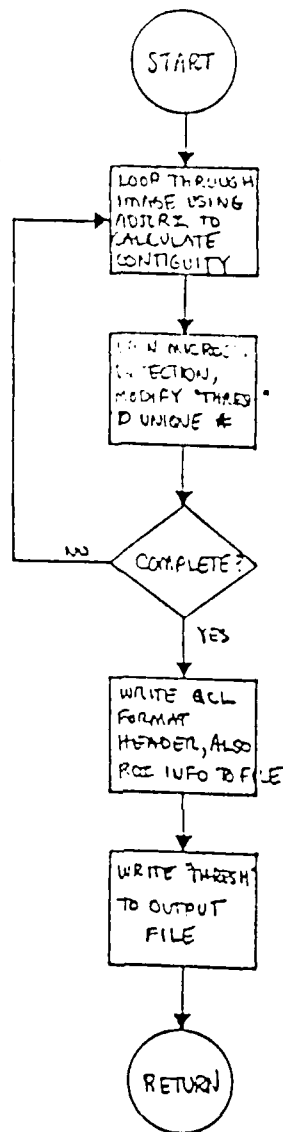
SUBROUTINE: STATIS

-CALCULATE STATISTICS
ON EACH
MICROSTRUCTURE.
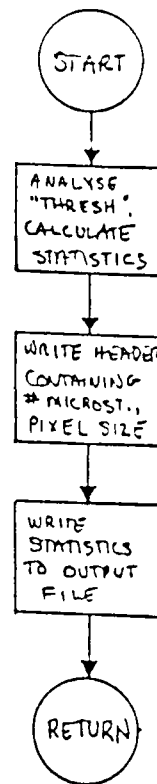
SUBROUTINE: ANLZST

-MICROSTRUCTURAL
DATA ANALYSIS.

START

PROMPT USER
TO ENTER
NAME OF
STATISTICS
FILE

DISPLAY ALL
POSSIBLE
DISPLAYABLE
STATISTICS,
OPTIONS

USER SELECTS
OPTION
WITH
CURSOR

exit → RETURN

- CIRCLES OF CONFIDENCE
- MODIFY X Y RANGE
- SELECT X Y - AXIS LABELS
- SELECT NEW DATA
- HARDCOPY
- EXIT

PLOT

READ IN THE
STATS FROM
FILE INTO
X Y ARRAYS

PLOT IN
UPPER 2/3
SCREEN

CALCULATE
REGRESSION &
CIRCLES OF
CONFIDENCE,
PLOT.
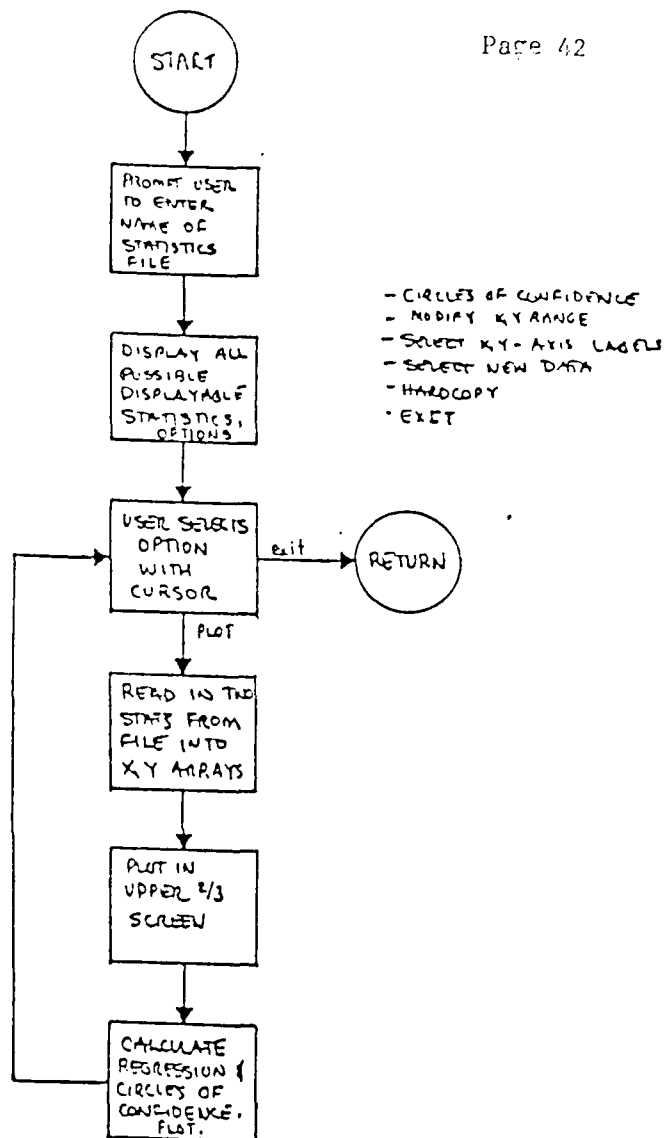
Appendix B. MSAR Program Code

```
          PROGRAM MSAR
C
C...      Read in a REAL *4 image from VAX, measure microstructure
C...      information (e.g. number, geometric X&Y center, weighted X&Y center,
C...      area, perimeter length, perimeter count, maximum horizontal and
C...      vertical feret diameters, Integrated Optical Density and average
C...      Optical Density).
C
          INCLUDE 'EDC_MSARCOM.FOR'
          BYTE INFTXT(80)
          DATA IOPT/1/
C
C...      PRINT RUNNING INFO TO USER
C
          OPEN(UNIT=1,NAME='[EDC.TASKS]EDC_MSAR_TEXT.FOR',TYPE='OLD',
     CREADONLY)
5         READ(1,10,END=15),NCHAR,(INFTXT(J),J=1,NCHAR)
10        FORMAT(Q,<NCHAR>A1)
          TYPE 12,(INFTXT(J),J=1,NCHAR)
12        FORMAT(' '<NCHAR>A1)
          GOTO 5
15        CLOSE(UNIT=1,DISPOSE='SAVE')
          TYPE 16
16        FORMAT('$TYPE CARRIAGE RETURN TO CONTINUE : ')
          ACCEPT 17,INFTXT(1)
17        FORMAT(A1)
C
C
C...      DISPLAY INFO TO USER IN MENU SCREEN.
C
          CALL WRTTMP
          CALL WRTINF
C
C...      DISPLAY MENU TO USER AT BOTTOM OF SCREEN
C
20        CALL WRTMEN
C
C...      DISPLAY MENU SELECTION CURSOR.  WAIT FOR USER TO SELECT OPTION
C
          CALL SELOPT(IOPT)
          GOTO (100,200,300,400,500,600),IOPT
          GOTO 20
C
100       CALL NFNAME                 !SET NEW FILENAME
          GOTO 20
200       IF(FNMSET .EQ. 0) GOTO 900  !CHECK IF FILENAME NOT SPECIFIED
          CALL DEFROI                 !DEFINE ROI
          GOTO 20
300       CALL ADJCRI                 !ADJACENCY CRITERIA
          GOTO 20
400       CALL SETTHR                 !SET THRESHOLDS
          GOTO 20
500       IF(FNMSET .EQ. 0) GOTO 900  !CHECK IF FILENAME NOT SPECIFIED
          CALL EXCUTE                 !EXECUTE
          GOTO 20
600       CALL CLRSCR                 !EXIT FROM ENTIRE PROGRAM
          CALL CLRTXT
          STOP
C
C...      OPERATION CANNOT BE PERFORMED UNLESS FILE HAS BEEN READ INTO MEMORY
```

```
C
900     CALL CLRLIN(19,23)              !CLEAR LINES 19-23 (MENU LOCATION)
        CALL SCROLL(19,23)             !SET SCROLL REGION FOR 19-23
        TYPE 910
910     FORMAT(/' OPERATION CANNOT BE PERFORMED UNTIL FILE HAS BEEN
     C READ INTO MEMORY'/)
        T=SECNDS(0.)
920     CONTINUE
        IF(SECNDS(0.)-T .LT. 2.0) GOTO 920
        CALL SCROLL(1,24)
        CALL CLRLIN(19,23)
        GOTO 20
C
        END
C
C
C
C
C
```

```
        SUBROUTINE WRTTMP
C
C...    WRITE TEMPLATE TO TERMINAL
C
        CALL CLRTXT
        CALL VTCURP(4,1)
        TYPE 100
        TYPE 120
        TYPE 130
        TYPE 140
        TYPE 150
        TYPE 160
        TYPE 170
        TYPE 180
        TYPE 185
        TYPE 190
        TYPE 200
100     FORMAT('+FILENAME: '/)
120     FORMAT(' ')
130     FORMAT(' THRESHOLD RANGE                         ROI')
140     FORMAT('    LOWER:            UPPER:            ROWS:
     C            COLUMNS: ')
150     FORMAT(' THRESHOLD INCREMENT:                   X-LEFT:
     C          Y-TOP: ')
160     FORMAT('    LOWER_INCR:       UPPER_INCR:       X-RIGHT:
     C          Y-BOTTOM: ')
170     FORMAT(' ')
180     FORMAT(' ADJACENCY CRITERIA: ')
185     FORMAT(' PIXEL DIMENSION:          MICRONS')
190     FORMAT(' ')
200     FORMAT(' PROGRAM STATUS: ')
C
        RETURN
        END
C
C
C
C
C
```

```
        SUBROUTINE WRTMEN
C
C...    WRITE MENU TO TERMINAL
C
        CHARACTER*10 OPTION(6)
        INTEGER *2 OPTLEN(6),OPTLIN(6),OPTCOL(6)
        BYTE BOLD(4),ATTOFF(4),REVERS(4)
        DATA OPTION(1) /'FILENAME  '/           !MENU OPTIONS
        DATA OPTION(2) /'DEFINE ROI'/
        DATA OPTION(3) /'ADJACENCY '/
        DATA OPTION(4) /'THRESHOLD '/
        DATA OPTION(5) /'EXECUTE   '/
        DATA OPTION(6) /'EXIT      '/
        DATA OPTLEN/8,10,9,9,7,4/              !LENGTH OF MENU OPTIONS
        DATA OPTLIN/20,20,20,22,22,22/
        DATA OPTCOL/1,20,39,1,20,39/
        DATA BOLD/27,91,49,109/               !ESC [ 1 m
        DATA ATTOFF/27,91,48,109/             !ESC [ 0 m
        DATA REVERS/27,91,55,109/             !ESC [ 7 m
C
        TYPE 90,(BOLD(J),J=1,4)
90      FORMAT('+'4A1)
        DO 100 IOPT=1,6
        CALL VTCURP(OPTLIN(IOPT),OPTCOL(IOPT))
        TYPE 95,OPTION(IOPT)(1:10)
95      FORMAT('+'A10)
100     CONTINUE
        RETURN
        END
C
C
C
C
C
```

```
            SUBROUTINE SELOPT(IOPT)
            CHARACTER*10 OPTION(6)
            INTEGER *2 OPTLEN(6),OPTLIN(6),OPTCOL(6)
            BYTE BOLD(4),ATTOFF(4),REVERS(4),BLINK(4)
            DATA OPTION(1) /'FILENAME  '/           !MENU OPTIONS
            DATA OPTION(2) /'DEFINE ROI'/
            DATA OPTION(3) /'ADJACENCY '/
            DATA OPTION(4) /'THRESHOLD '/
            DATA OPTION(5) /'EXECUTE   '/
            DATA OPTION(6) /'EXIT      '/
            DATA OPTLEN/8,10,9,9,7,4/               !LENGTH OF MENU OPTIONS
            DATA OPTLIN/20,20,20,22,22,22/
            DATA OPTCOL/1,20,39,1,20,39/
            DATA BOLD/27,91,49,109/                 !ESC [ 1 m
            DATA ATTOFF/27,91,48,109/               !ESC [ 0 m
            DATA REVERS/27,91,55,109/               !ESC [ 7 m
            DATA BLINK/27,91,53,109/                !ESC [ 5 m
C
            JOPT=IOPT
C
60          TYPE 90,(ATTOFF(J),J=1,4)       !RETURN 'OLD' OPTION TO NORMAL
            TYPE 90,(BOLD(J),J=1,4)         !HOWEVER, BOLD THE OPTION
            CALL VTCURP(OPTLIN(JOPT),OPTCOL(JOPT))
            TYPE 95,OPTION(JOPT)(1:10)
C
            TYPE 90,(REVERS(J),J=1,4)       !'REVERSE' 'NEW' OPTION
C           TYPE 90,(BLINK(J),J=1,4)        !'BLINK' 'NEW' OPTION
90          FORMAT('+'4A1)
            CALL VTCURP(OPTLIN(IOPT),OPTCOL(IOPT))
            TYPE 95,OPTION(IOPT)(1:10)
95          FORMAT('+'A10)
            CALL VTCURP(23,1)
C
C...        WAIT FOR USER TO MOVE MENU CURSOR
C
            IKEY=0
            TLAST=SECNDS(0.)                !SECONDS SINCE LAST INPUT
100         I=IESC(IKEY)
            IF(IKEY .EQ. 0) THEN
                    IF(SECNDS(0.)-TLAST .GT. 3600.) THEN
                            IOPT=6
                            GOTO 999
                    END IF
                    GOTO 100
            END IF
            IF(IKEY .EQ. 13) GOTO 999       !<CR> USER ACCEPTS IOPT
            IF(IKEY .LT. 65 .OR. IKEY .GT. 68) GOTO 100
            JOPT=IOPT
            IF(IKEY .EQ. 65) THEN           !UP ARROW
                    IOPT=IOPT-3
                    IF(IOPT .LT. 1) IOPT=IOPT+6
            END IF
            IF(IKEY .EQ. 66) THEN           !DOWN ARROW
                    IOPT=IOPT+3
                    IF(IOPT .GT. 6) IOPT=IOPT-6
            END IF
            IF(IKEY .EQ. 67) THEN           !RIGHT ARROW
                    IOPT=IOPT+1
                    IF(IOPT .GT. 6) IOPT=1
            END IF
```

```
        IF(IKEY .EQ. 68) THEN          !LEFT ARROW
                IOPT=IOPT-1
                IF(IOPT .LT. 1) IOPT=6
        END IF
        GOTO 60
C
999     TYPE 90, (ATTOFF(J), J=1, 4)    !RETURN OPTION TO NORMAL
        RETURN
        END
C
C
C
C
C
```

```
          SUBROUTINE NFNAME
          INCLUDE 'EDC_MSARCOM.FOR'
C
C...      SETUP SOME PARAMETERS
C
          IRROW=512
          IRCOL=512
          IRXTOP=1
          IRYTOP=1
          IRXBOT=512
          IRYBOT=512
C
C...      CLEAR MENU SECTION OF VT SCREEN
C
          CALL CLRLIN(19,23)                !CLEAR LINES 19-23 (MENU LOCATION)
          CALL SCROLL(19,23)                !SET SCROLL REGION FOR 19-23
C
C...      PROMPT USER FOR FILENAME
C
80        DO 90 J=1,14
90        FNAME(J)=0
          TYPE 100
100       FORMAT('$ENTER FILENAME AND EXTENSION : ')
          ACCEPT 120,NCHAR,(FNAME(J),J=1,NCHAR)
120       FORMAT(Q,13A1)
          IF(NCHAR .EQ. 0) THEN
                  CALL SCROLL(1,24)
                  CALL CLRLIN(19,23)
                  GOTO 999
          END IF
C
C...      GET PIXEL DIMENSIONS FROM USER
C
300       TYPE 320
320       FORMAT(' ENTER PHYSICAL DIMENSION OF PIXEL IN MICRONS
     C <ie 0.25>')
          TYPE 330
330       FORMAT('$TYPE <CR> IF UNKNOWN : ')
          ACCEPT 340,NCHAR,SIZPIX
340       FORMAT(Q,F15.5)
          IPIXFG=0                  !SET PIXEL FLAG=0
          IF(NCHAR .EQ. 0) THEN
                  IPIXFG=1          !SET PIXEL FLAG SINCE USER DIDN'T KNOW SIZE
                  SIZPIX=1.0
          END IF
C
C...      OPEN INPUT FILE
C
          OPEN(UNIT=3,NAME=FNAME,TYPE='OLD',READONLY,FORM='UNFORMATTED',
     C ERR=900)
C
C...      READ IMAGE INTO MEMORY
C
          TYPE 350
350       FORMAT(/////' READING IMAGE FILE INTO MEMORY'///)
          READ (3) TEMP
          CLOSE(UNIT=3,DISPOSE='SAVE')
          NCOLS=512
          NROWS=512
          DO 400 J=1,512                           !TRANSFER TO I*2 ARRAY
```

```
        DO 400 K=1,512
400     IMAGE(K,J)=IINT(TEMP(K,J))
C
C...    WRITE NEW INFORMATION TO TERMINAL
C
        CALL SCROLL(1,24)
        CALL WRTINF                 !WRITE INFO TO SCREEN
        CALL CLRLIN(19,23)
        FNMSET=1                    !SET FLAG TO INDICATE FILE READ SUCCESFULLY
C
999     RETURN
C
C
900     TYPE 910
910     FORMAT(' ERROR IN OPENING FILE, PLEASE REENTER')
        GOTO 80
        END
C
C
C
C
C
```

```
        SUBROUTINE DEFROI
        INCLUDE 'EDC_MSARCOM.FOR'
C
C...    CLEAR MENU SECTION OF VT SCREEN
C
        CALL CLRLIN(18,23)              !CLEAR LINES 18-23 (MENU LOCATION)
        CALL SCROLL(18,23)             !SET SCROLL REGION FOR 18-23
C
C...    KEYPAD ENTRY
C
200     TYPE 220
220     FORMAT(//'$ENTER X,Y COORDINATES OF TOP LEFT CORNER OF ROI : ')
        ACCEPT 240,NCHAR,I1,I2
240     FORMAT(Q,2I4)
        IF(NCHAR .EQ. 0) GOTO 999
        IF(I1 .LT. 0 .OR. I2 .LT. 0) GOTO 300
        IF(I1 .GT. NCOLS .OR. I2 .GT. NROWS) GOTO 300
C
250     TYPE 260
260     FORMAT('$ENTER X,Y CORRDINATES OF BOTTOM RIGHT CORNER OF ROI : ')
        ACCEPT 240,NCHAR,I3,I4
        IF(NCHAR .EQ. 0) GOTO 999
        IF(I3 .LT. I1 .OR. I4 .LT. I2) GOTO 320
        IF(I3 .GT. NCOLS .OR. I4 .GT. NROWS) GOTO 300
C
        IRXTOP=I1
        IRYTOP=I2
        IRXBOT=I3
        IRYBOT=I4
        IRROW=IRYBOT-IRYTOP+1
        IRCOL=IRXBOT-IRXTOP+1
        GOTO 999
C
C...    ERRORS IN ENTERING ROI INFORMATION
C
300     TYPE 310
310     FORMAT(' BOUNDARY DEFINITION ARE OUTSIDE OF LEGAL RANGE'/)
        GOTO 200
320     TYPE 330
330     FORMAT(' BOTTOM RIGHT MUST BE BELOW AND TO THE RIGHT OF TOP LEFT')
        GOTO 250
C
999     CALL SCROLL(1,24)
        CALL WRTINF             !WRITE INFO TO SCREEN
        CALL CLRLIN(18,23)
C
        RETURN
        END
C
C
C
C
C
```

```
            SUBROUTINE SETTHR
            INCLUDE 'EDC_MSARCOM.FOR'
            BYTE ACEPT
C
C...        CLEAR MENU SECTION OF VT SCREEN
C
            CALL CLRLIN(19,23)              !CLEAR LINES 19-23 (MENU LOCATION)
            CALL SCROLL(19,23)             !SET SCROLL REGION FOR 19-23
C
C...        GET THRESHOLD VALUES FROM USER
C
90          TYPE 100
100         FORMAT('$ENTER INITIAL LOWER,UPPER THRESHOLD VALUES : ')
            ACCEPT 120,NCHAR,I1,I2
120         FORMAT(Q,2I4)
            IF(NCHAR .EQ. 0) GOTO 999
            IF(I1 .LT. 0 .OR. I2 .LT. I1) GOTO 800
            IF(I2 .GT. 255 .OR. I1 .GT. I2) GOTO 800
C
            TYPE 160
160         FORMAT('$ENABLE THRESHOLD INCREMENTATION ? <N/Y> : ')
            ACCEPT 170,NCHAR,ACEPT
170         FORMAT(Q,A1)
            IF(ACEPT .EQ. 'Y') GOTO 190
C
C...        USER DID NOT WANT THRESHOLD INCREMENTATION.  SET VALUES AND RETURN
C
            ITLOW=I1
            ITUPR=I2
            ITINCR=0
            ITLINC=0
            ITUINC=0
            GOTO 999
C
C...        GET INCREMENTATION VALUES FROM USER
C
190         TYPE 200
200         FORMAT('$ENTER LOWER,UPPER THRESHOLD INCREMENT VALUES : ')
            ACCEPT 120,NCHAR,I3,I4
            IF(NCHAR .EQ. 0) GOTO 999
            IF(I3 .GT. 255 .OR. I4 .GT. 255) GOTO 820
            IF(I3 .EQ. 0 .AND. I4 .EQ. 0) GOTO 840
C
C...        SET VALUES AND RETURN
C
            ITLOW=I1
            ITUPR=I2
            ITINCR=1
            ITLINC=I3
            ITUINC=I4
            GOTO 999
C
800         TYPE 810
810         FORMAT(/' INVALID THRESHOLD VALUES.   PLEASE RE-ENTER'/)
            GOTO 90
C
820         TYPE 830
830         FORMAT(/' THRESHOLD INCREMENT VALUE CANNOT EXCEED 255.   PLEASE
     C RE-ENTER'/)
            GOTO 190
```

```
C
840     TYPE 850
850     FORMAT(/' INVALID INCREMENT VALUES.   PLEASE RE-ENTER'/)
        GOTO 190
C
999     CALL SCROLL(1,24)
        CALL WRTINF                !WRITE INFO TO SCREEN
        CALL CLRLIN(18,23)
C
        RETURN
        END
C
C
C
C
C
```

```
        SUBROUTINE ADJCRI
        INCLUDE 'EDC_MSARCOM.FOR'
C
C...    CLEAR MENU SECTION OF VT SCREEN
C
        CALL CLRLIN(19,23)                !CLEAR LINES 19-23 (MENU LOCATION)
        CALL SCROLL(19,23)                !SET SCROLL REGION FOR 19-23
C
C...    GET USER INPUT AND CHANGE ADJACENCY CRITERIA
C
90      TYPE 100
100     FORMAT(/' SELECT CRITERIA BY WHICH POINTS ARE CONSIDERED
      C CONTIGUOUS'/' 1-ORTHOGONAL POINTS ONLY'/' 2-ORTHOGONAL AND
      C DIAGONAL POINTS')
        TYPE 120
120     FORMAT('$ENTER SELECTION : ')
        ACCEPT 140,NCHAR,ISEL
140     FORMAT(Q,I2)
        IF(NCHAR .EQ. 0) GOTO 999
        IF(ISEL .LT. 1 .OR. ISEL .GT. 2) GOTO 90
        IF(ISEL .EQ. 1) IADJCT=0
        IF(ISEL .EQ. 2) IADJCT=1
C
999     CALL SCROLL(1,24)
        CALL WRTINF              !WRITE INFO TO SCREEN
        CALL CLRLIN(19,23)
C
        RETURN
        END
C
C
C
C
C
```

```
          SUBROUTINE EXCUTE
          INCLUDE 'EDC_MSARCOM.FOR'
C
C...      SAVE INITIAL THRESHOLD VALUES
C
          JTLOW=ITLOW
          JTUPR=ITUPR
          NUMAVG=0
C
C...      CHANGE PROGRAM STATUS TO 'EXECUTING'
C
          STATUS=2
          CALL WRTINF
C
C...      OPEN OUTPUT FILE TO CONTAIN 'AVERAGE' INFORMATION OF MICROSTRUCTURES
C
          OPEN(UNIT=2,NAME='MICROS.DAT',TYPE='UNKNOWN',ACCESS='APPEND')
          DO 10 J=1,14
          IF(FNAME(J) .EQ. '.') GOTO 15
10        CONTINUE
          NCHAR=14
          GOTO 20
15        NCHAR=J+3
20        WRITE(2,25),(FNAME(J),J=1,NCHAR),IRXTOP,IRYTOP,IRXBOT,IRYBOT
25        FORMAT(//' FILENAME = '<NCHAR>A1//' REGION OF INTEREST   -
     CTOP LEFT (X='I3',Y='I3'), BOTTOM RIGHT (X='I3',Y='I3')'//)
          WRITE(2,30)                              !PUT OUT HEADER OF FIRST SECTION
30        FORMAT('
     C                                    AVERAGE     AVERAGE'/
     C'                                    NUMBER      AVERAGE
     C     AVERAGE     AVERAGE    WEIGHTED    WEIGHTED'/
     C' THRESHOLD     TOTAL       OBJECTS      OBJECT
     C     X-          Y-          X-          Y-'/
     C'  RANGE        AREA     (MICROSTRUCTURES)   AREA
     C      CENTER      CENTER       CENTER      CENTER'/)
C
C
C...      CLEAR MENU SECTION OF VT SCREEN
C
          CALL CLRLIN(19,23)                 !CLEAR LINES 19-23 (MENU LOCATION)
          CALL SCROLL(19,23)                 !SET SCROLL REGION FOR 19-23
C
C...      GO THROUGH THE INPUT IMAGE FILE IN ARRAY 'IMAGE', THRESHOLD USING
C...      THE USER-SUPPLIED VALUES, AND PLACE THE BINARY RESULT IN 'THRESH'.
C...      ONLY BE CONCERNED WITH THE REGION OF INTEREST.
C
50        DO 100 I=IRYTOP,IRYBOT
          TYPE 99,I
99        FORMAT(' THRESHING LOC 'I3)
          DO 100 J=IRXTOP,IRXBOT
          IF(IMAGE(J,I) .GE. ITLOW .AND. IMAGE(J,I) .LE. ITUPR) THEN
                 THRESH(J,I)=1
C...  *** NOTE - NEXT LINE OF CODE IS FOR VERTICAL FILL OF IMAGE.
                 IF(IMAGE(J,I-1) .LT. ITLOW .OR. IMAGE(J,I-1)
     C.GT. ITUPR) THRESH(J,I-1)=-1
          ELSE
                 THRESH(J,I)=0
          END IF
100       CONTINUE
C
```

```
C...      GO BACK INTO IMAGE AND SEARCH FOR -1 FLAG.   IF FOUND, PUT THE VALUE
C...      OF THE PIXEL DIRECTLY VERTICAL TO THE PRESENT PIXEL INTO PRESENT
C...      LOCATION.
C
          DO 2100 I=IRYTOP,IRYBOT
          TYPE 99,I
          DO 2100 J=IRXTOP,IRXBOT
          IF(THRESH(J,I) .EQ. -1) THEN
                  THRESH(J,I)=1
                  IMAGE(J,I)=IMAGE(J,I+1)
          END IF
2100      CONTINUE
C
C...      CALL SUBROUTINE 'CONTIG' TO CALCULATE THE CONTIGUOUS STRUCTURES
C...      IN THE USER-DEFINED ROI AND USING THE USER-SPECIFIED ADJACENCY
C...      CRITERIA.   RESULT OF THIS SUBROUTINE WILL BE UNIQUELY LABEL
C...      MICROSTRUCTURES IN THE ARRAY 'THRESH'.
C
          CALL CONTIG
          TYPE 101,UNIQUE
101       FORMAT(' UNIQUE NUMBER = 'I7)
          T=SECNDS(O.)
102       CONTINUE
          IF(SECNDS(O.)-T .LT. 2.0) GOTO 102
C
C...      CALL SUBROUTINE 'STATIS' TO CALCULATE THE STATISTICS ON EACH
C...      OF THE UNIQUE MICROSTRUCTURES IN THE ARRAY 'THRESH'.   WRITE
C...      OUTPUT TO OUTPUT FILE
C
          CALL STATIS(NUMAVG)
C
C...      WAS THRESHOLDING INCREMENTATION ENABLED?
C
          IF(ITINCR .EQ. 0) GOTO 900
C
C...      INCREMENT THRESHOLDS
C
          ITLOW=ITLOW+ITLINC
          ITUPR=ITUPR+ITUINC
          IF(ITLOW .LT. 0 .OR. ITLOW .GT. 255) GOTO 900 !OUTSIDE VALID RANGE
          IF(ITUPR .LT. 0 .OR. ITUPR .GT. 255) GOTO 900
          IF(ITLOW .GT. ITUPR) GOTO 900
C
C...      WRITE INFORMATION TO TERMINAL
C
          CALL SCROLL(1,24)
          CALL WRTINF
          CALL CLRLIN(19,23)                !CLEAR LINES 19-23 (MENU LOCATION)
          CALL SCROLL(19,23)                !SET SCROLL REGION FOR 19-23
          GOTO 50
C
C...      RESET INITIAL THRESHOLD AND THEN RETURN
C
900       ITLOW=JTLOW
          ITUPR=JTUPR
C
C...      PUT A <FF> IN FILE TO SEPERATE THIS RUN
C
          WRITE(2,910),12
910       FORMAT(' ',A1)
```

```
C...      WRITE SECOND PAGE OF INFO
          WRITE(2,915)
915       FORMAT('                                    AVERAGE
     C                  AVERAGE     AVERAGE'/
     C'                TOTAL       PERIMETER                        A
     CVERAGE       HORIZ      VERTICAL                      AVERAGE
     C        AVERAGE'/
     C' THRESHOLD    PERIMETER      POINTS         TOTAL      PERI
     CMETER      FERET       FERET       CUMULATIVE       IOD
     C       ODmax'/
     C'   RANGE        POINTS      PER OBJECT     PERIMETER    PER O
     CBJECT    DIAMETER    DIAMETER       IOD         PER OBJECT
     C PER OBJECT'/)
          DO 930 J=1,NUMAVG
          WRITE(2,920),IAVG(J,1),IAVG(J,2),IAVG(J,3),GAVG(J,1),GAVG(J,7),
     CGAVG(J,2),GAVG(J,3),GAVG(J,4),IAVG(J,4),GAVG(J,5),GAVG(J,6)
920       FORMAT('    ',I3,'-',I3,6X,I6,5X,F10.2,4X,F10.2,6X,F7.2,6X,F7.2,
     C5X,F7.2,5X,I10,3X,F12.2,4X,F7.2)
930       CONTINUE
          WRITE(2,910),12
          CLOSE(UNIT=2,DISPOSE='SAVE')     !CLOSE 'AVERAGE' FILE
C
999       CALL SCROLL(1,24)
          STATUS=1                    !RESET STATUS TO USER-INPUT
          CALL WRTINF                 !WRITE INFO TO SCREEN
          CALL CLRLIN(18,23)
C
          RETURN
          END
C
C
C
C
C
```

```
        SUBROUTINE CONTIG
        INCLUDE 'EDC_MSARCOM.FOR'
        BYTE OUTFIL(22),LOW(3),UPR(3),EXT(3)
        INTEGER*2 START(256),STOP(256),IADJPT(512),DROP(65536),MAP(65536)
        DATA EXT/'M','C','S'/
C
        UNIQUE=1
        IDROP=0
C
C...    LOOP THROUGH ALL LINES
C
        DO 450 IROW=IRYTOP,IRYBOT
        TYPE 451,IROW
451     FORMAT(' ROW = 'I7)
C
C...    SEARCH LINE FOR START AND STOP OF STRUCTURES ON LINE.  THE ARRAYS
C...    START(*) AND STOP(*) CONTAIN THE STARTING AND STOPPING LOCATIONS
C...    OF ALL THE STRUCTURES ON THAT LINE.  'ISNUM' CONTAINS THE NUMBER OF
C...    STRUCTURES.
C
        ISNUM=0
        JCOL=IRXTOP
90      IF(THRESH(JCOL,IROW) .EQ. 0) GOTO 140
        ISNUM=ISNUM+1
        START(ISNUM)=JCOL
100     JCOL=JCOL+1
        IF(JCOL .GT. IRXBOT) GOTO 110
        IF(THRESH(JCOL,IROW) .EQ. 1) GOTO 100
110     STOP(ISNUM)=JCOL-1
140     JCOL=JCOL+1
        IF(JCOL .LE. IRXBOT) GOTO 90
C
C...    SEARCH EACH STRUCTURE FOR CONTIGUOUS STRUCTURES ABOVE
C
        DO 400 ISTRCT=1,ISNUM
        IF(IROW .EQ. IRYTOP) GOTO 360              !TOP ROW
C
C...    LOOP THROUGH STRUCTURE.  SEARCH FOR ADJACENT STRUCTURES.  IF FOUND,
C...    MAKE NOTE OF UNIQUE NUMBER OF ADJACENT STRUCTURE.
C
        IADJ=0
        DO 300 JCOL=START(ISTRCT),STOP(ISTRCT)
        IF(THRESH(JCOL,IROW-1) .EQ. 0) GOTO 200
C...    ADJACENT POINT FOUND
        IF(IADJ .EQ. 0) GOTO 190
        DO 180 J=1,IADJ
        IF(THRESH(JCOL,IROW-1) .EQ. IADJPT(J)) GOTO 200 !UNIQUE # ALREADY FOUND
180     CONTINUE
190     IADJ=IADJ+1
        IADJPT(IADJ)=THRESH(JCOL,IROW-1)
C
200     IF(IADJCT .EQ. 0) GOTO 300                  !DONT CHECK FOR DIAGONALS
        IF(JCOL-1 .LT. IRXTOP) GOTO 230            !DONT CHECK OUTSIDE ROI
        IF(THRESH(JCOL-1,IROW-1) .EQ. 0) GOTO 230
C...    ADJACENT POINT FOUND
        IF(IADJ .EQ. 0) GOTO 220
        DO 210 J=1,IADJ
        IF(THRESH(JCOL-1,IROW-1) .EQ. IADJPT(J)) GOTO 230       !UNIQUE # ALREADY FOUND
210     CONTINUE
220     IADJ=IADJ+1
```

```
                IADJPT(IADJ)=THRESH(JCOL-1,IROW-1)
C
230             IF(JCOL+1 .GT. IRXBOT) GOTO 300          !DONT CHECK OUTSIDE ROI
                IF(THRESH(JCOL+1,IROW-1) .EQ. 0) GOTO 300
C...            ADJACENT POINT FOUND
                IF(IADJ .EQ. 0) GOTO 250
                DO 240 J=1,IADJ
                IF(THRESH(JCOL+1,IROW-1) .EQ. IADJPT(J)) GOTO 300      !UNIQUE # ALREADY FOUND
240             CONTINUE
250             IADJ=IADJ+1
                IADJPT(IADJ)=THRESH(JCOL+1,IROW-1)
300             CONTINUE
C
                IF(IADJ .EQ. 0) GOTO 360           !NO ADJACENT POINTS. ASSIGN NEXT VALUE
                IF(IADJ .EQ. 1) GOTO 380           !ONE ADJACENT POINT
C
C...            MORE THAN ONE STRUCTURE IS ADJACENT.  SET PRESENT STRUCTURE TO LOWEST
C...            ADJACENT STRUCTURE VALUE, THEN SEARCH FOR AND RESET ALL OTHER PREVIOUS
C...            STRUCTURE VALUES TO THAT SAME LOW VALUE.  SEARCH BY GOING FROM PREVIOUS
C...            LINE TO THE FIRST LINE (BOTTOM TO TOP).  WHEN STRUCTURE VALUE IS NO
C...            LONGER ENCOUNTERED, DROP IT FROM THE SEARCH
C
                IMIN=99999
                DO 310 J=1,IADJ                    !SELECT MINIMUM STRUCTURE VALUE
                IF(IADJPT(J) .LT. IMIN) IMIN=IADJPT(J)
310             CONTINUE
C
                DO 315 J=1,IADJ                    !MAKE NOTE OF DROPPED VALUES
                IF(IADJPT(J) .EQ. IMIN) GOTO 315
                IDROP=IDROP+1
                DROP(IDROP)=IADJPT(J)
315             CONTINUE
C
                DO 320 JCOL=START(ISTRCT),STOP(ISTRCT)  !ASSIGN MIN VALUE TO 'THRESH'
                THRESH(JCOL,IROW)=IMIN
320             CONTINUE
C
                DO 350 K=1,IADJ
                IF(IADJPT(K) .EQ. IMIN) GOTO 340          .      !DON'T DROP IMIN VALUE
                DO 340 I=IROW-1,IRYTOP,-1
                IFLG=0
                DO 330 J=IRXTOP,IRXBOT
                IF(THRESH(J,I) .NE. IADJPT(K)) GOTO 330
                THRESH(J,I)=IMIN                          !RESET VALUE
                IFLG=1
330             CONTINUE
                IF(IFLG .EQ. 0) GOTO 350          !DIDN'T FIND ON LINE. STOP SEARCH
340             CONTINUE
350             CONTINUE
                GOTO 400
C
C...            ASSIGN THE STRUCTURE NEXT UNIQUE VALUES.  NO ADJACENT POINTS
C
360             DO 370 JCOL=START(ISTRCT),STOP(ISTRCT)
                THRESH(JCOL,IROW)=UNIQUE
370             CONTINUE
                UNIQUE=UNIQUE+1
                GOTO 400
C
C...            ASSIGN THE STRUCTURE THE VALUE OF THE SINGLE ADJACENT STRUCTURE
```

```
C
380       DO 390 JCOL=START(ISTRCT),STOP(ISTRCT)
          THRESH(JCOL,IROW)=IADJPT(1)
390       CONTINUE
          GOTO 400
C
400       CONTINUE
450       CONTINUE
C
C...      AT THIS POINT, THRESH CONTAINS UNIQUELY LABELLED MICROSTRUCTURES.
C...      HOWEVER, THE UNIQUE NUMBERS MUST BE COMPRESSED SINCE MANY VALUES
C...      WERE DROPPED.  THE VALUES DROPPED ARE IN THE ARRAY 'DROP(IDROP)'.
C...      THIS IS ACCOMPLISHED BY CREATED A 'MAP', COMPRESSING THE MAP AND
C...      THEN USING THAT COMPRESSED MAP TO ALTER THE VALUES IN 'THRESH'
C
          UNIQUE=UNIQUE-1
C
          TYPE 452,UNIQUE
452       FORMAT(' NUMBER OF MSTs BEFORE COMPRESSION = 'I10//'$: ')
          TYPE 454,UNIQUE,IDROP
454       FORMAT(' UNIQUE = 'I7'  IDROP = 'I7)
          ICTMAP=0
C
          MAP(0)=0                          !CLEAR MAP
          DO 600 J=1,UNIQUE
600       MAP(J)=0
C
          DO 610 JD=1,IDROP                 !SETUP DROPPED POINTS
610       MAP(DROP(JD))=-1
C
          DO 620 J=1,UNIQUE                 !FILL IN MAP
          IF(MAP(J) .EQ. -1) THEN
                  MAP(J)=0
                  GOTO 620
          END IF
          ICTMAP=ICTMAP+1
          MAP(J)=ICTMAP
620       CONTINUE
          UNIQUE=ICTMAP
C
          DO 640 IROW=IRYTOP,IRYBOT         !APPLY MAP TO 'THRESH'
          DO 640 JCOL=IRXTOP,IRXBOT
          IF(THRESH(JCOL,IROW) .EQ. 0) GOTO 640
          THRESH(JCOL,IROW)=MAP(THRESH(JCOL,IROW))
640       CONTINUE
C
C...      WRITE TO OUTPUT FILE
C
          CALL CONFNM(OUTFIL,EXT)           !GET OUTPUT FILENAME
          OPEN(UNIT=3,NAME=OUTFIL,TYPE='NEW')
          NCHANS=1                          !ONE CHANNEL OF DATA
          NHEADR=2                          !NUMBER OF HEADER LINES
          WRITE(3,650),NROWS,NCOLS,NCHANS,NHEADR
650       FORMAT(4I4)
C...      TYPE CHANNEL USED, ROI INFO, ADJACENCY FLAG AND THRESHOLD RANGE
          WRITE(3,670),ICHAN,IRXTOP,IRYTOP,IRXBOT,IRYBOT,IADJCT,ITLOW,ITUPR
670       FORMAT(8I7)
C...      WRITE 'THRESH' ARRAY TO FILE
          DO 685 I=IRYTOP,IRYBOT
          WRITE(3,680),(THRESH(J,I),J=IRXTOP,IRXBOT)
```

```
680     FORMAT(2216)
685     CONTINUE
        CLOSE(UNIT=3,DISPOSE='SAVE')
C
C

        RETURN
        END
C
C
C
C
C
```

```
          SUBROUTINE STATIS(NUMAVG)
          INCLUDE 'EDC_MSARCOM.FOR'
          INTEGER*2 COORD(2,8),PERMCT,ORTHO,DIAG,ODmax,PERMC1,ICOUNT(8)
          INTEGER ODmaxS
          BYTE OUTFIL(22),EXT(3)
          DATA COORD/-1,-1,-1,0,-1,1,0,1,1,1,1,0,1,-1,0,-1/
          DATA EXT/'M','S','T'/
          SGRTWO=2**0.5
C
C...      OPEN FILE FOR MICROSTRUCTURE STATISTICS.  WRITE HEADER INFO
C
          CALL CONFNM(OUTFIL,EXT)          !GET OUTPUT FILENAME
          OPEN(UNIT=3,NAME=OUTFIL,TYPE='NEW')
          WRITE(3,10),OUTFIL,ITLOW,ITUPR
10        FORMAT(' FILENAME = '22A1,T40' LOWER THRESHOLD = 'I3'    UPPER
      C THRESHOLD = 'I3)
          WRITE(3,12),UNIQUE              !#MST,PIX SIZE, SIZE FLAG
12        FORMAT(' 'I5' UNIQUE MICROSTRUCTURES FOUND. ')
          IF(IPIXFG .NE. 1) THEN
                WRITE(3,14),SIZPIX,IPIXFG
14              FORMAT(' ACTUAL PIXEL SIZE = 'F7.3' MICRONS.  FLAG = 'I2)
          ELSE
                WRITE(3,16),SIZPIX,IPIXFG
16              FORMAT(' DEFAULT PIXEL SIZE = 'F7.3' MICRONS.  FLAG = 'I2)
          END IF
          WRITE(3,22)
          WRITE(3,24)
          WRITE(3,26)
22        FORMAT(////'                                      WEIGHTED WEIGHTED
      C                                    MAXIMUM      MAXIMUM')
24        FORMAT('      UNIQUE          X        Y        X         Y
      C PERIMETER    PERIMETER    HORIZONTAL     VERTICAL
      C          AVERAGE')
26        FORMAT(' MICROSTRUCTURE   CENTER    CENTER    CENTER    CENTER
      C     AREA     COUNT      LENGTH     RUN-LENGTH   RUN-LENGTH     IOD
      C   IOD    ODmax'/)
C
C...      CLEAR SOME VALUES
C
          IAREAS=0
          XCEN1=0
          YCEN1=0
          XWCEN1=0
          YWCEN1=0
          XTCENT=0
          YTCENT=0
          PERMC1=0
          PERIM1=0.
          IMAX_X_SUM=0
          IMAX_Y_SUM=0
          IODSUM=0
          ODmaxS=0
C
C...      CALCULATE STATISTICS FOR ALL MICROSTRUCTURES
C
          DO 900 IMST=1,UNIQUE
C
C...      SEARCH FOR FIRST OCCURANCE OF MICROSTRUCTURE #IMST
C
          DO 100 IROW=IRYTOP,IRYBOT
```

```
         DO 100 ICOL=IRXTOP,IRXBOT
         IF(THRESH(ICOL,IROW) .EQ. IMST) GOTO 110
100      CONTINUE
C
C...     CALCULATE PERIMETER BE SEARCHING ADJACENT POINTS.  IF IADJCT=0,
C...     SEARCH #2,4,6,8.   IF IADJCT=1, SEARCH #1,2,3,4,5,6,7,8.
C...
C...                       1 2 3
C...                       8 * 4
C...                       7 6 5
C
C...     SINCE FIRST POINT WAS FOUND BY SEARCHING FROM THE LEFT (FROM #8)
C...     WITH NOTHING IN THE PREVIOUS LINE, THE FIRST SEARCH POINT IS
C...     #4.    AFTER A POINT IS FOUND, SEARCH FOR THE NEXT POINT BY STARTING
C...     AT (PREVIOUS SEARCH # + 4 +1) OR (P.S.# - 4 + 1) IF P.S.# >= 4.
C
C
110      IPSRC=4
         ISRC=IPSRC
         PERMCT=0                            !COUNT OF PERIMETER
         ORTHO=0                             !COUNT OF ORTHOGONAL POINTS
         DIAG=0                              !COUNT OF DIAGONAL POINTS
         IYMIN=IROW                          !SET PARAMETERS FOR BLOB RANGE
         IYMAX=IROW
         IXMIN=ICOL
         IXMAX=ICOL
         IYST=IROW
         IXST=ICOL
C
120      IF(IYST+COORD(1,ISRC) .LT. IRYTOP .OR. IYST+COORD(1,
     CISRC) .GT. IRYBOT) GOTO 125                   !CHECK IF OUT OF ROI
         IF(IXST+COORD(2,ISRC) .LT. IRXTOP .OR. IXST+COORD(2,
     CISRC) .GT. IRXBOT) GOTO 125
         IF(THRESH(IXST+COORD(2,ISRC),IYST+COORD(1,ISRC)) .NE. 0) GOTO 160
125      ISRC=ISRC+1
         IF(IADJCT .EQ. 0) ISRC=ISRC+1             !ONLY CHECK ORTHO POINTS
         IF(ISRC .GT. 8) ISRC=ISRC-8
         IF(ISRC .NE. IPSRC) GOTO 120
C...     POINT IS ISOLATED. PERIMETER IS 1 POINT
         PERMCT=1
         GOTO 200
C
160      IF(JMOD(ISRC,2) .EQ. 0) THEN              !DETERMINE IF ORTHO OR DIAG
             ORTHO=ORTHO+1
         ELSE
             DIAG=DIAG+1
         END IF
         IYST=IYST+COORD(1,ISRC)                   !MOVE TO NEW POINT
         IXST=IXST+COORD(2,ISRC)
         IF(THRESH(IXST,IYST) .GT. 0) THEN
             PERMCT=PERMCT+1  !COUNT 'NEW' POINT
             THRESH(IXST,IYST)= -THRESH(IXST,IYST)    !NEGATE POINT AS FLAG
         END IF
C
C...     AT THIS POINT, YOU MUST CHECK IF ALL SURROUNDING POINTS HAVE BEEN
C...     COUNTED.   SEARCH AND SEE IF ALL SURROUNDING POINT OF THE PRESENT
C...     MICROSTRUCTURE HAVE BEEN SET TO -VALUE
C
         IF(IYST .EQ. IROW .AND. IXST .EQ. ICOL) THEN
```

```
              IADJ_COUNT=0
              IADJ_NOT_COUNT=0
              ISKIP=2
              IF(IADJCT .EQ. 1) ISKIP=1
              DO 170 ICHK=ISKIP,8,ISKIP
              IF(IYST+COORD(1,ICHK) .LT. IRYTOP .OR. IYST+COORD(1,
      CICHK) .GT. IRYBOT) GOTO 170                    !CHECK IF OUT OF ROI
              IF(IXST+COORD(2,ICHK) .LT. IRXTOP .OR. IXST+COORD(2,
      CICHK) .GT. IRXBOT) GOTO 170
              IF(THRESH(IXST+COORD(2,ICHK),IYST+COORD(1,ICHK)) .LT. 0) THEN
                      IADJ_COUNT=IADJ_COUNT+1
                      ICOUNT(IADJ_COUNT)=ICHK
              END IF
              IF(THRESH(IXST+COORD(2,ICHK),IYST+COORD(1,ICHK)) .GT. 0)
      C IADJ_NOT_COUNT=IADJ_NOT_COUNT+1
170           CONTINUE
              IF(IADJ_NOT_COUNT .EQ. 0) GOTO 200              !BACK AT 1ST POINT
              IF(IADJ_COUNT .EQ. 1) GOTO 180                  !CONTINUE SEARCH
              DO 172 JJ=1,IADJ_COUNT-1
              DO 172 KK=2,IADJ_COUNT
              IDIF=IABS(ICOUNT(JJ)-ICOUNT(KK))
              IF(IDIF .EQ. 1 .OR. IDIF .EQ. 7) GOTO 172
              GOTO 200                          !SEPERATED BY TWO, BACK AT 1ST POINT
172           CONTINUE
              GOTO 180
              END IF
C
C
C             ISKIP=2
C             IF(IADJCT .EQ. 1) ISKIP=1
C             DO 170 ICHK=ISKIP,8,ISKIP
C             IF(IYST .LT. 60) GOTO 173
C             TYPE 172,IXST,IYST,ICHK,THRESH(IXST+COORD(2,ICHK),IYST+COORD(1,ICHK))
C172          FORMAT(' IXST = 'I5'   IYST = 'I5'   ICHK = 'I4'    THRESH = 'I7)
C173          IF(THRESH(IXST+COORD(2,ICHK),IYST+COORD(1,ICHK)) .EQ. 0) THEN
C                     IZRFLG=0
C                     GOTO 170
C             END IF
C             IF(THRESH(IXST+COORD(2,ICHK),IYST+COORD(1,ICHK)) .LT. 0) IZRFLG=1
C             IF(THRESH(IXST+COORD(2,ICHK),IYST+COORD(1,ICHK)) .GT. 0
C     C.AND. IZRFLG .EQ. 0) GOTO 180
C170          CONTINUE
C             GOTO 200                     !BACK AT 1ST POINT
C             END IF
C
C...          SET RANGE VALUES
180           IF(IYST .LT. IYMIN) IYMIN=IYST
              IF(IYST .GT. IYMAX) IYMAX=IYST
              IF(IXST .LT. IXMIN) IXMIN=IXST
              IF(IXST .GT. IXMAX) IXMAX=IXST
C...          CALCULATE WHERE TO LOOK NEXT
              IF(ISRC .LE. 4) THEN
                      IPSRC=ISRC+4
              ELSE
                      IPSRC=ISRC-4
              END IF
              IPSRC=IPSRC+2
              IF(IPSRC .GT. 8) IPSRC=IPSRC-8
              ISRC=IPSRC
```

```
        GOTO 120
C
C...    CALCULATE PERIMETER DISTANCE
C
200     PERIM=(ORTHO+(DIAG*SQRTWO))*SIZPI:         !NORMALIZED TO MICRONS
C
C...    SECOND PASS THROUGH RANGE THAT CONTAINS MICROSTRUCTURE.
C...    DETERMINE MAX HORIZONTAL AND VERITICAL DIAMETERS
C
        IMAX_Y=0
        IMAX_X=0
        DO 320 ICOL=IXMIN,IXMAX              !CALCULATE Y-MAX DIAMETER
        IST=0
        DO 300 IROW=IYMIN,IYMAX
        IF(IABS(THRESH(ICOL,IROW)) .EQ. IMST) THEN
                IF(IST .EQ. 1) GOTO 290
                IST=1
                ISTLC=IROW
290             CONTINUE
        ELSE
                IF(IST .EQ. 0) GOTO 295
                IF((IROW-1)-ISTLC .GT. IMAX_Y) IMAX_Y=IROW-1-ISTLC
                IST=0
295             CONTINUE
        END IF
300     CONTINUE
                IF(IST .EQ. 0) GOTO 320
                IF((IROW-1)-ISTLC .GT. IMAX_Y) IMAX_Y=IROW-1-ISTLC
320     CONTINUE
C
C...    THIRD PASS THROUGH RANGE THAT CONTAINS MICROSTRUCTURE.   DETERMINE
C...    GEOMETRIC CENTER, AREA, IOD, ODmax, AND AVERAGE OPTICAL DENSITY.
C
C...    CLEAR ALL ARRAYS
        IAREA=0
        IYSUM=0
        IXSUM=0
        WYSUM=0.
        WXSUM=0.
        IOD=0
        ODmax=-1
C
        DO 420 IROW=IYMIN,IYMAX
        IST=0
        DO 400 ICOL=IXMIN,IXMAX
        IF(IABS(THRESH(ICOL,IROW)) .EQ. IMST) THEN
                IIMG=IMAGE(ICOL,IROW)
                IF(IST .EQ. 1) GOTO 390
                IST=1
                ISTLC=ICOL
390             IAREA=IAREA+1
                IYSUM=IYSUM+IROW
                IXSUM=IXSUM+ICOL
                IOD=IOD+IIMG
                WYSUM=WYSUM+FLOAT(IROW*IIMG)
                WXSUM=WXSUM+FLOAT(ICOL*IIMG)
                IF(IIMG .GT. ODmax) ODmax=IIMG
        ELSE
                IF(IST .EQ. 0) GOTO 395
                IF((ICOL-1)-ISTLC .GT. IMAX_X) IMAX_X=ICOL-1-.STLC
```

```
                IST=0
395             CONTINUE
        END IF
400     CONTINUE
            IF(IST .EQ. 0) GOTO 420
            IF((ICOL-1)-ISTLC .GT. IMAX_X) IMAX_X=ICOL-1-ISTLC
420     CONTINUE
        IMAX_Y=IMAX_Y+1
        IMAX_X=IMAX_X+1
        YCENT=FLOAT(IYSUM)/FLOAT(IAREA)          !GEOMETRIC CENTERS
        XCENT=FLOAT(IXSUM)/FLOAT(IAREA)
        YWCENT=WYSUM/FLOAT(IOD)
        XWCENT=WXSUM/FLOAT(IOD)
        AREA=FLOAT(IAREA)*(SIZPIX*SIZPIX)        !NORMALIZED AREA
        AVGOD=FLOAT(IOD)/FLOAT(IAREA)            !AVERAGE OPTICAL DENSITY
        IF(IAREA .EQ. PERMCT) THEN               !NO 'INTERIOR' POINTS
            PERMCT=-1
            PERIM=-1.0
        END IF
C
C...    WRITE INFORMATION TO FILE
C
        WRITE(3,800), IMST, XCENT, YCENT, XWCENT, YWCENT, AREA, PERMCT,
    CPERIM, IMAX_X, IMAX_Y, IOD, AVGOD, ODmax
800     FORMAT(' 'T6, I5, T18, F7.2, T27, F7.2, T36, F7.2, T45, F7.2, T53, F9.2,
    CT64, I5, T74, F8.2, T89, I3, T102, I3, T109, I8, T118, F7.2, T127, I3)
C
C...    KEEP A RUNNING TOTAL OF ALL STATISTICS FOR THIS THRESHOLD RANGE.
C...    THIS WILL BE WRITTEN TO AN OUTPUT FILE AT COMPLETION OF ALL PARTICLES
C
        XCEN1=XCEN1+XCENT                       !X AND Y CENTERS
        YCEN1=YCEN1+YCENT
        XTCENT=XTCENT+(XCENT*IOD)
        YTCENT=YTCENT+(YCENT*IOD)
        XWCEN1=XWCEN1+XWCENT                    !WEIGHTED X AND Y CENTERS
        YWCEN1=YWCEN1+YWCENT
        IAREAS=IAREAS+IAREA                     !TOTAL AREA
        IF(PERMCT .LT. 0) GOTO 820
        PERMC1=PERMC1+PERMCT                    !TOTAL PERIMETER COUNT
820     IF(PERIM .LT. 0) GOTO 830
        PERIM1=PERIM1+PERIM                     !TOTAL PERIMETER LENGTH
830     IMAX_X_SUM=IMAX_X_SUM+IMAX_X            !TOTAL X,Y-RUN LENGTH
        IMAX_Y_SUM=IMAX_Y_SUM+IMAX_Y
        IODSUM=IODSUM+IOD                       !TOTAL IOD
        ODmaxS=ODmaxS+ODmax                     !TOTAL ODmax
C
900     CONTINUE
        CLOSE(UNIT=3, DISPOSE='SAVE')
C
C...    CALCULATE 'AVERAGE' OF STATISTICS AND WRITE TO UNIT 2
C
        IF(UNIQUE .LT. 1) THEN
            AUNO=0
            AOUT1=0
            AOUT2=0
            AOUT3=0
            AOUT6=0
            AOUT7=0
            GOTO 950
        END IF
```

```
            AUNQ=FLOAT(UNIQUE)
            AOUT1=FLOAT(IAREAS)/AUNQ
            AOUT2=XCEN1/AUNQ
            AOUT3=YCEN1/AUNQ
            AOUT6=XTCENT/FLOAT(IODSUM)
            AOUT7=YTCENT/FLOAT(IODSUM)
950         WRITE(2,920),ITLOW,ITUPR,IAREAS,UNIQUE,AOUT1,AOUT2,AOUT3,
      CAOUT6,AOUT7
920         FORMAT('   ',I3,'-',I3,6X,I6,11X,I6,11X,F9.2,5X,F7.2,6X,F7.2,
      C6X,F7.2,7X,F7.2)
C...        STORE STATS FOR SECOND SECTION OF OUTPUT
            NUMAVG=NUMAVG+1
            IAVG(NUMAVG,1)=ITLOW
            IAVG(NUMAVG,2)=ITUPR
            IF(UNIQUE .LT. 1) THEN
                    IAVG(NUMAVG,3)=0
                    IAVG(NUMAVG,4)=0
                    GAVG(NUMAVG,1)=0.
                    GAVG(NUMAVG,2)=0.
                    GAVG(NUMAVG,3)=0.
                    GAVG(NUMAVG,4)=0.
                    GAVG(NUMAVG,5)=0.
                    GAVG(NUMAVG,6)=0.
                    GAVG(NUMAVG,7)=0.
            ELSE
                    IAVG(NUMAVG,3)=PERMC1
                    IAVG(NUMAVG,4)=IODSUM
                    GAVG(NUMAVG,1)=FLOAT(PERMC1)/AUNQ
                    GAVG(NUMAVG,2)=PERIM1/AUNQ
                    GAVG(NUMAVG,3)=FLOAT(IMAX_X_SUM)/AUNQ
                    GAVG(NUMAVG,4)=FLOAT(IMAX_Y_SUM)/AUNQ
                    GAVG(NUMAVG,5)=FLOAT(IODSUM)/AUNQ
                    GAVG(NUMAVG,6)=FLOAT(ODmaxS)/AUNQ
                    GAVG(NUMAVG,7)=PERIM1
            END IF
999         RETURN
            END
C
C
C
C
C
```

```
        SUBROUTINE CONFNM(OUTFIL,EXT)
        INCLUDE 'EDC_MSARCOM.FOR'
        BYTE OUTFIL(22),LOW(3),UPR(3),EXT(3)
C                                                  !COPY FILENAME
        DO 700 JPOINT=1,14
        IF(FNAME(JPOINT) .EQ. '.') GOTO 710
        OUTFIL(JPOINT)=FNAME(JPOINT)
700     CONTINUE
710     ENCODE(3,3,LOW),ITLOW
        ENCODE(3,3,UPR),ITUPR
3       FORMAT(I3)
        OUTFIL(JPOINT)='_'
        OUTFIL(JPOINT+4)='_'
        DO 715 J=1,3
        IF(LOW(J) .EQ. ' ') LOW(J)='0'
        IF(UPR(J) .EQ. ' ') UPR(J)='0'
        OUTFIL(JPOINT+J)=LOW(J)
        OUTFIL(JPOINT+J+4)=UPR(J)
715     CONTINUE
        OUTFIL(JPOINT+8)='.'
        OUTFIL(JPOINT+9)=EXT(1)
        OUTFIL(JPOINT+10)=EXT(2)
        OUTFIL(JPOINT+11)=EXT(3)
C
        RETURN
        END
C
C
C
C
C
```

```
        SUBROUTINE WRTINF
        INCLUDE 'EDC_MSARCOM.FOR'
        BYTE BOLD(4),ATTOFF(4),REVERS(4),BLINK(4)
        DATA BOLD/27,91,49,109/                     !ESC [ 1 m
        DATA ATTOFF/27,91,48,109/                   !ESC [ 0 m
        DATA REVERS/27,91,55,109/                   !ESC [ 7 m
        DATA BLINK/27,91,53,109/                    !ESC [ 5 m
C
        ITOP=4
C
        CALL VTCURP(ITOP,11)                        !FILENAME
        TYPE 100,FNAME
        CALL VTCURP(ITOP+4,10)                      !LOWER THRESHOLD
        TYPE 140,ITLOW
        CALL VTCURP(ITOP+4,27)                      !UPPER THRESHOLD
        TYPE 140,ITUPR
        CALL VTCURP(ITOP+6,15)                      !LOWER_INCR
        TYPE 140,ITLINC
        CALL VTCURP(ITOP+6,32)                      !UPPER_INCR
        TYPE 140,ITUINC
        CALL VTCURP(ITOP+4,48)                      !ROWS
        TYPE 140,IRROW
        CALL VTCURP(ITOP+4,69)                      !COLUMNS
        TYPE 140,IRCOL
        CALL VTCURP(ITOP+5,49)                      !X-TOP
        TYPE 140,IRXTOP
        CALL VTCURP(ITOP+5,67)                      !Y-TOP
        TYPE 140,IRYTOP
        CALL VTCURP(ITOP+6,52)                      !X-BOTTOM
        TYPE 140,IRXBOT
        CALL VTCURP(ITOP+6,70)                      !Y-BOTTOM
        TYPE 140,IRYBOT
C
        CALL VTCURP(ITOP+5,22)                      !THRESHOLD INCREMENT
        IF(ITINCR .EQ. 1) THEN
                TYPE 150
        ELSE
                TYPE 160
        END IF
C
        CALL VTCURP(ITOP+8,21)                      !ADJACENCY CRITERIA
        IF(IADJCT .EQ. 1) THEN
                TYPE 170
        ELSE
                TYPE 180
        END IF
C
        CALL VTCURP(ITOP+9,18)                      !PIXEL DIMENSION
        IF(IPIXFG .EQ. 1) THEN
                TYPE 190                            !USER DID NOT KNOW DIMENSION
        ELSE
                TYPE 200,SIZPIX
        END IF
C
        IF(STATUS .EQ. 1) THEN                      !PROGRAM STATUS
                TYPE 230,ATTOFF
                CALL VTCURP(ITOP+11,17)
                TYPE 210
        ELSE
                TYPE 230,BOLD
```

```
                    TYPE 230, REVERS
                    TYPE 230, BLINK
                    CALL VTCURP(ITOP+11,17)
                    TYPE 220
                    TYPE 230, ATTOFF
              END IF
C
100           FORMAT('+',14A1)
120           FORMAT('+',I1)
140           FORMAT('+',I3)
150           FORMAT('+ENABLED ')
160           FORMAT('+DISABLED')
170           FORMAT('+ORTHOGONAL/DIAGONAL')
180           FORMAT('+ORTHOGONAL          ')
190           FORMAT('+*******')
200           FORMAT('+',F7.3)
210           FORMAT('+USER-INPUT')
220           FORMAT('+EXECUTING ')
230           FORMAT('+',4A1)
C
C
              RETURN
              END
C
C
C
C
C
```

```
        SUBROUTINE VTCURP(LINE,COL)
C
C...    PLACE CURSOR AT LINE & COL OF SCREEN
C
        IMPLICIT INTEGER*2(A-Z)
        BYTE CP(8)    !HORIZONTAL & VERTICAL CURSOR POSITION
        DATA CP/27,91,48,48,59,48,48,72/ !ESC [ 0 0 ; 0 0 H
        ENCODE(2,2,CP(3))LINE
        ENCODE(2,2,CP(6))COL
2       FORMAT(I2)
        IF (CP(3) .EQ. ' ') CP(3) = '0'
        IF (CP(6) .EQ. ' ') CP(6) = '0'
        TYPE 10,CP
10      FORMAT('$'8A1)
C
        RETURN
        END
C
C
C
C
C
```

```
        SUBROUTINE CLRTXT
        BYTE COMAND(4)
        DATA COMAND/27,91,50,74/
C
        TYPE 100,COMAND
100     FORMAT('+'4A1)
        RETURN
        END
C
C
C
C
C
        SUBROUTINE CLRLIN(ITOP,IBOT)
        BYTE MOVE(7),ERASE(4)
        DATA MOVE/27,91,0,0,59,49,72/                   !ESC [ P1 ; 1 H
        DATA ERASE/27,91,50,75/                         !ESC [ 2 K
C
        DO 200 J=ITOP,IBOT
        ILINE=J
        MOVE(3)='0'
        IF(ILINE .GT. 9) MOVE(3)=(ILINE/10)+48
        MOVE(4)=JMOD(ILINE,10)+48
        TYPE 100,MOVE              !MOVE CURSOR TO LINE
        TYPE 100,ERASE            !ERASE ALL OF LINE
100     FORMAT('+'7A1)
200     CONTINUE
        RETURN
        END
C
C
C
C
C
        SUBROUTINE CLRSCR
        BYTE INIT(3),END(2)
        DATA INIT/27,80,112/           !ESC P p
        DATA END/27,92/                !ESC \
C
        TYPE 100,INIT,END
100     FORMAT('+'3A1,'S(E)',2A1)
        RETURN
        END
C
C
C
C
C
```

```
        SUBROUTINE VTDBLE(TEXT, NCHARS, LINE, COL, VID)
C
C...    DOUBLE WIDTH VT TERMINAL TEXT PROGRAM
C
C
C       CALLING VARIABLES:
C
C       TEXT    - input string of text
C       NCHARS  - input number of characters of the text [0-40]
C                   if nchars = 0, simply set the existing text to double width
C       LINE    - input line of text [ 1 - 23 ]
C       COL     - input starting column of text [ 1 - 40 ]
C       VID     - normal (0) or reverse (1) video
C
      IMPLICIT INTEGER*2(A-Z)
      BYTE DW(3), TEXT(40), CP(8), Rv(4), Nv(3)
      DATA CP/27, 91, 48, 48, 59, 48, 48, 72/ !CURSOR POSITION
      DATA DW/27, 35, 54/   !DOUBLE WIDTH SINGLE HEIGHT
      DATA RV/27, 91, 55, 109/    !ESC [ 7 m    REVERSE VIDEO
      DATA NV/27, 91, 109/       !ESC [ m     NORMAL VIDEO
      IF (LINE   .LT.   1) LINE   = 1  !VT SCREEN LINES FROM 1
      IF (LINE   .GT.  23) LINE   = 23  !                    TO 23
      IF (COL    .LT.   1) COL    = 1
      IF (COL    .GT.  40) COL    = 40
      IF (NCHARS + COL .GT.  41) NCHARS = 41 - COL
      ENCODE(2, 2, CP(3))    LINE
      ENCODE(2, 2, CP(6))    COL
    2 FORMAT(I2)
      IF (CP(3) .EQ.  ' ') CP(3) = '0' !ZERO FILL 1 DIGIT NUMBERS
      IF (CP(6) .EQ.  ' ') CP(6) = '0'
      IF (NCHARS .LE.   0) THEN     !make existing text double width
        TYPE 10, CP, DW
        return
      end if
      if (vid .eq. 1) then
        type 10, Cp, Dw, Rv, (Text(i), i=1, Nchars), Nv  !reverse video text
      else
        type 10, CP, DW, Nv, (TEXT(I), I=1, NCHARS)      !normal video text
      end if
   10 FORMAT('$', 58A1)
      RETURN
      END
C
C
C
C
C
```

```
C
C
C
C
C        ASYNCHRONOUS KEYBOARD INPUT USING SYSTEM SERVICES QIO
C        WITH WAIT FOR EVENT FLAG TO PREVENT POLLING.
C
C........................................................
C
C
         FUNCTION IESC ( CHAR )
C
         IMPLICIT INTEGER*2 ( A - Z )
         LOGICAL*1 FLAG
         INTEGER*2 IESC_EFN
         INTEGER*2 IOSB(4)
         INTEGER*2 IESC_CHAN
         INTEGER*2 NEXT(4)
         BYTE FIRST_CHAR
         BYTE LAST_TWO_CHARS(2)
C
         CHARACTER*2 TERMINAL / 'TT' /
C
C
         DATA      FLAG / .FALSE. /
C
         INCLUDE   '( $IODEF )'         !DEFINE SYMBOLIC NAMES FOR I/O FUNCTION
C                                        CODE  IO$READVBLK AND IO$M_NOECHO, THE
C                                        CODE MODIFIER.
C
C........................................................
C
      CHAR = 0
      IESC = 0
      IESC_EFN = 2
      IF (FLAG) GO TO 10
      ISTAT = SYS$ASSIGN (TERMINAL,IESC_CHAN,,)
      IF ( .NOT. ISTAT )  CALL LIB$STOP ( %VAL (ISTAT ) )
      FLAG = .TRUE.
10    IO_FUNC = IO$_READVBLK .OR. IO$M_NOECHO .OR. IO$M_ESCAPE
      IO_TEST = IO$_SENSEMODE .OR. IO$M_TYPEAHDCNT
      ISTAT = SYS$QIOW(%VAL(IESC_EFN) ,      ! READ A CHARACTER
     1               %VAL(IESC_CHAN),        ! WHEN KEYED.
     2               %VAL(IO_FUNC  ),        !
     3               %REF(IOSB     ),        !
     4               ,                       !
     5               ,                       !
     6               %REF(FIRST_CHAR),       !
     7               %VAL(1),                !
     8               ,                       !
     9               ,                       !
     1               ,  )                    !
C                                            !
C
      IF (.NOT. ISTAT ) CALL LIB$STOP (%VAL(ISTAT)) ! STOP IF QIO NOT SUCCESS
      CHAR = FIRST_CHAR
      ISTAT = SYS$QIOW(%VAL(IESC_EFN),          !HOW MANY MORE CHARACTERS
     1               %VAL(IESC_CHAN),
     2               %VAL(IO_TEST) ,
     3               %REF( IOSB) ,
```

```
     4              .
     5             '
     6                   %REF(NEXT),,,,, )
C              .
      IF( NEXT(1) .EQ. 0 )  RETURN
C
      ISTAT = SYS$QIOW(%VAL(IESC_EFN),                !GET THE REST
     1                  %VAL(IESC_CHAN),
     2                  %VAL(IESC_FUNC),
     3                  %REF(     IOSB),
.    4              .  '
     5             '
     6                   %REF(LAST_TWO_CHARS),%VAL(2),,,,)
C
      CHAR = LAST_TWO_CHARS(2)
      IESC = 1
C
C     WRITE (6,100) IESC,IDUM
CC100  FORMAT (6X,'BYTE COUNT: ' ,I4, ' FIRST CHARACTER: ',A1 )
C
20     RETURN
      END
C
C
C
C
C
```

```
        SUBROUTINE SCROLL(ITOP,IBOT)
C
C...    SET SCROLL REGION TO ONE DEFINED BY ITOP,IBOT.   THEN MOVE
C...    CURSOR TO 'HOME', TOP LINE OF SCROLL REGION.
C
        BYTE INIT(2),STRING(6)
        DATA INIT/27,91/                    !ESC [
C
        STRING(1)=(ITOP/10)+48
        STRING(2)=(ITOP-((STRING(1)-48)*10))+48
        STRING(3)=';'
        STRING(4)=(IBOT/10)+48
        STRING(5)=(IBOT-((STRING(4)-48)*10))+48
        STRING(6)='r'
C
        TYPE 10,"33,(STRING(J),J=1,6)
10      FORMAT('+',A1,'[',6A1)
        TYPE 20,INIT
20      FORMAT('+'2A1,'?6h')
        RETURN
        END
```